ANNEX 1

# Social, regulatory and technical factors involved when considering a transition to the DRM system

## 1 System overview

This section addresses the technical and economic factors involved in bringing the advantages of digital sound broadcasting to all listeners around the world and considers how DRM family of transmission standards can serve to bring these to the public as a standard for digital sound broadcasting. The DRM30 standard covers digital sound broadcasting the LF, MF and HF bands and the DRM+ standard covers the VHF broadcasting bands I, II and III.

The first DRM standard (DRM30) was developed in order to provide a way of re-engineering sound broadcasting in the LF, MF and HF bands so as to provide far superior audibility and reliability. Audio quality with DRM30 is perceived as coming close to FM quality for most in-home, portable and in-car use.

The transition to the DRM30 standard would lead to major savings in transmission power and electricity costs – down to between half or a quarter of conventional AM transmitter requirements – coupled with audio quality close to FM. DRM therefore offers broadcasters providing international, national and regional services an excellent opportunity to cut costs, simplify their operations and attract new audiences to high quality programming. The advantages of economy and quality are particularly attractive when considering upgrading national AM networks. DRM has the potential to revitalize the bands previously used for AM broadcasting.

The planning aspects and the implications on spectrum use of making a complete transition to the DRM30 transmission standard in the LF, MF and HF bands are examined in Attachment 1 to this Annex. The conclusions therein are based on numerous proving tests (e.g. Annex 3 to Report ITU-R BS.2144), together with the recent experience gained by from fully engineered live trials of DRM30 transmissions, as reported in detail in Attachment 1 to this Annex.

The issues are not so clear though when it comes to replacing FM broadcasting. The reason for introducing FM broadcasting at VHF frequencies in the 1950s was mainly to overcome the noise and interference evident with AM broadcasting, particularly from ever more prevalent noise from unsuppressed car ignition systems. Later, of course, the advantages of higher audio quality and stereo programming became the main drivers of audience acceptance and demand. Likewise, digital systems must be seen to provide not just additional features, but features whose advantages are very obvious to the general public – not hidden deep within the system specification.

By providing high quality stereo broadcasting to receivers in the home environment, FM has become the world standard for sound broadcasting, and can be considered as meeting the pragmatic engineering objective, valid in all fields of technology, of being *“as good as it needs to be”*. Nevertheless, there are deficiencies: FM broadcasting does not make the best use of the available spectrum, which in turn places limitations on coverage and listener choice. FM planning is still based on the original expectation that domestic reception would be on a main radio set connected to an external antenna at rooftop level. The available signal level is therefore not always sufficient for the usual situation nowadays that most listening is indoors on portable receivers or in cars. Multi-path reception of additional time-delayed signals, reflected from natural and man-made structures adds to the problems so that annoying drop-outs and interference are often experienced, especially in built-up areas or in terrain with no clear line of sight path to the transmitter, resulting in noisy, squawky reception.

The digital sound broadcasting systems developed for use at VHF, including DRM+, have therefore focused on using modulation and audio coding schemes that can overcome the effect of multiple radio signal reflections and thus provide dependable quality of service in cars or with portable receivers. However, the DRM+ system offers further technical advantages over FM in being able to use the available bandwidth for additional service offerings.

Each DRM+ signal only takes up half the bandwidth of an FM emission yet delivers the same audio quality and has the flexibility to organize the available data throughput in a variety of ways for additional programme content or other data purposes. For example, broadcasters have the option to combine locally to provide mini local multiplexes of 2, 3 or 4 programme streams, depending on quality and coverage requirements within the bandwidth of a single FM transmission. However, it remains the case that switching off FM broadcasting, which carries a wide range of programming genres, with coverage ranging from national networks to very localized community stations, would prove a major disruption to established patterns of listening. In order to command public acceptance and support, the complete transition to digital sound broadcasting should at least preserve and, ideally, expand on the range and diversity of content currently available with FM.

The planning aspects and the implications on spectrum use of making a complete transition to the DRM+ transmission standard in the VHF bands are examined in Attachment 2 to this Annex. The conclusions therein are based on numerous proving tests carried out prior to the inclusion of DRM+ as System G in Recommendation ITU-R BS.1114, together with the recent experience gained by from fully engineered live trials of DRM+ transmissions, as reported in detail in Attachment 2 to this Annex.

## 2 Key features of DRM technology

The DRM family of standards can provide a comprehensive solution to all digital sound broadcasting needs. DRM technology can be tailored to suit the requirements of any type of sound broadcasting from wide-coverage, national and international stations to community stations, in all the commonly used wavebands through the DRM30 (LF. MF and HF bands) and DRM+ (VHF Bands I, II and III) standards.

The range of options available with DRM technology will allow for:

a) scaling and matching coverage for the distribution of local, regional, national and international programming precisely to service requirements, while allowing the single transmitter per service area model to be retained where appropriate;

b) operation over single frequency networks where appropriate for providing the optimum coverage solution;

c) operation in digital mode only or combined with the existing analogue transmission (AM or FM signal) in “simulcast” mode;

d) provision of mini-multiplexes in the VHF bands providing additional programme content or languages, or both, where the multiplexed broadcasting model is preferred;

e) provision of Early Warning System (EWS) with alert information presentable in the form of audio or text messages; and

f) provision of data streams for multimedia applications that can expand the range of services offered by broadcasters and benefit the listener accordingly.

Moreover, various added value audio and data services are available. This is particularly useful when implementing DRM30 in the LF, MF and HF bands, where transmission characteristics can been chosen so as to emphasize robustness or quality, or in order to provide stereo of dual language programming, as well as a variety of data services.

DRM, therefore, has the potential to bring every listener a vast selection of additional content, either related to the programme content or for completely different purposes. The supplementary digital data streams available within the DRM standards can be used to provide a variety of added value services, accessible through a link to a personal computer or a self-contained display device.

Several types of additional content are possible, singly or in combination:

– Additional visual/text based programme related features possible with DRM include:
  - electronic programme guides;
  - full speech text or commentary on the programme;
  - web pages and links to the programme content;
  - Journaline text based information service (Unicode), supporting all classes of receivers, triggers interactivity and geo-awareness access;
  - additional content for advertisers, such as text or web-based material for supplementing the voice advert with more details on the products, local suppliers, pricing, ordering etc.;
  - integrated text, graphics, web-pages, videos and slide shows with audio commentary;
  - screen-based control over interactivity and functionality.

– Additional audio based programme related features possible with DRM include:
  - stereo/surround sound/surround sound 5.1;
  - dual or multi language programme streams translating the main programme feed or for providing an alternative programme feed;
  - extended commentary on particular programme or advertising features.

– Additional audio/visual/text content provided under a public service remit or on revenue producing basis, which could include:
  - government or public-sector announcements or service information;
  - dedicated news streams or emergency broadcasts in time of crisis, natural disasters, extreme weather;
  - customer specific information services (e.g. stock/commodity/currency market information).

One of the simpler additional data service features to implement is a continuous feed of a selection of web pages, together with links to further web based content, which can then be displayed via a connection to a personal computer. This service was tested extensively by BBC World Service and Vosper-Thorneycroft Communications (now Babcock International Communications Limited) during 2005 by adding maritime safety information web pages from the United Kingdom’s Coastguard service, providing weather forecasts and warnings, to the subsidiary data stream during DRM30 test transmissions at HF. This was demonstrated to the International Maritime Organization on the occasion of the 10th session of the Sub-Committee on Radiocommunications and Search and Rescue in September 2005.

Another possibility for providing visual content within the DRM data stream is “Caption Radio”, in which text data stream are displayed on a small LCD or LED display. This can provide real time information on programme content, even the complete text of a speech programme in order to help those with hearing difficulties.

In September 2010, the DRM Consortium gave the first demonstration of a more extensive range of data based audio-visual possibilities through the Small Scale Video Application "Diveemo". This DRM based application for broadcasting "live" small-scale video and audio services could provide cost efficient, large area distribution of information and education programs in the AM broadcasting bands.

Adherence to international and regional standards has been a key objective in the development of the DRM family of transmission standards, as witness the following recent events:

– In November 2014, the DRM Consortium signed The Smart Radio Memorandum Of Understanding[1]. This has been developed by the EBU, along with leading European Public Service and Commercial Broadcasters, and other organizations throughout Europe, with the objectives to:
  - Improve popularity, access to and experience or radio
  - Launch and promote of free-to-air analogue and digital radio services
  - Provide access through various devices and especially mobile phones
  - Coordinate the activities of broadcaster and organisation members

– At the Visegrad radio digitisation conference in Banska Bystrica (Slovakia) in spring 2015, a Resolution was adopted after the Conference emphasising the necessity of bringing multi-standard radio receivers to the market. The final paragraph underlines the need for the industry to *"produce and in due time to put on the V4 market multi-standard receivers for all relevant systems in compliance with the EBU. Recommendation R138 (FM, T-DAB+, DRM)"* and *"equip all new cars with such receivers"*.

– In June 2015, ETSI published the revised standard ETSI ES 201 980v4.1.1 (2014-01) This version V4.1.1 defines the actual content to be transported in the DRM-specific RSCI[2] protocol. All of the DRM specifications at ETSI are now up to date with DRM+ and xHE-AAC[3].

## 3 Status of DRM implementations

The foremost strategic country for DRM remains India, which is on track to complete nationwide DRM30 broadcasting networks with the installation of new MF and HF transmitters, capable of covering 600 million people with a combined power of 8 000 kW.

On April 8, 2010, the government of India announced the approval of its core digitalization programme for All India Radio (AIR), its public broadcasting organization. AIR has chosen DRM as the technology for converting or replacing its vast analogue, mainly MF, transmitter network for digital operation. In an effort to improve the quality of MF transmissions, AIR has planned to convert and/or replace its MF transmitters by digital transmitters. In this process, 72 of the 148 MF transmitters are either being replaced or converted to digital transmitters.

AIR has already replaced one of its 1 000 kW transmitters at Rajkot (Gujarat) and it is already carrying regular digital transmissions. In addition to value added text services, the Rajkot digital

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1 See http://www3.ebu.ch/files/live/sites/ebu/files/Programming/Radio/Digital%20Radio/MOU_signed.pdf.

2 Receiver Status and Control Interface.

3 High Efficiency Advanced Audio Coding

transmitter has provision to work in simulcast mode wherein one radio programme can be broadcast in analogue mode (for reception on conventional AM radio sets) and another programme in digital mode, which can be received only on digital receivers. The Urdu service of AIR, which was being provided from the old transmitter at Rajkot, is still being broadcast in analogue mode from the new transmitter for reception on AM receivers, with the popular commercial service, known as *Vividh Bharati*, now being broadcast in digital mode from this transmitter.

The switch to DRM services is proceeding rapidly, with another 1 000 kW MF digital transmitter at Kolkata and six 20 kW digital transmitters at an advanced stage of installation. For the next phase of the MF switchover, orders for the replacement of six 300 kW, ten 200 kW and eleven 100 kW digital transmitters have recently been issued.

As of February 2018, All India Radio (AIR) has:

– 39 DRM30 transmitters already operational;

– 35 at MF of which 2 are working in pure DRM, 33 in simulcast (also 25 in pure DRM daily for 1 hour). Details of operation are available on official website (allindiaradio.org.in)

– 4 at HF

During the inauguration of the 300 kW DRM30 transmitter of ‘Radio Kashmir’ at Jammu on 19 May 2015, the Minister of State in the Prime Minister's Office (PMO) Jitendra Singh is reported as confirming the commitment to the empowerment of radio broadcast, and added that the government had initiated the revival of AIR, noting in particular that AIR can play an important role in the dissemination of various welfare schemes. The Director General of AIR Fiyaz Shehriyar said, *“As a part of migration to Digital Radio, it has been decided that by the year 2017, a complete switch over to digital mode will be made. All India Radio started with small leaps in this direction way back in 2013”*.[4]

As mentioned,most of the AIR transmitters presently simulcast, but tests and broadcasts of pure DRM broadcast are taking place. During 27 – 29 May 2015, AIR made pure digital transmission tests in DRM from a 20 kW transmitter in New Delhi on two channels and regular transmissions started on 19 June. AIR is thus transmitting on 1 368 kHz of *Vividh Bharati* and FM Rainbow in DRM digital mode from the 20 kW New Delhi transmitter[5][6][7].

The AIR Bengaluru transmitter is currently testing in simulcast mode, 612 kHz analogue + 621 kHz DRM. The transmission can be checked also on its streaming application at : www.airbenglauru.com.Consideration is also now being given to operating the 20kW transmitter at Chennai in pure digital mode.

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4 http://www.business-standard.com/article/news-ani/jitendra-singh-inaugurates-high-power-transmitter-in-jammu-115051900794_1.html.

5 http://www.business-standard.com/article/pti-stories/now-listen-vividh-bharati-fm-rainbow-in-digital-mode-115062501279_1.html.

6 http://economictimes.indiatimes.com/industry/media/entertainment/media/now-listen-vividh-bharati-fm-rainbow-in-digital-mode/articleshow/47820153.cms.

7 http://www.televisionpost.com/printradio/all-india-radio-enters-digital-transmission-era/.

In other developments, India's Transport Ministry has approved plans to provide the first traffic information system along the Delhi to Agra road[8] and, for the maritime community, special DRM test transmissions at HF are being planned for international cargo ships, with content mainly from AIR aimed at seafarers where the whole crew or a majority of the crew is from India – currently two cargo ships are taking part in the test transmissions.

As regards the availability of DRM receivers the first mass-market DRM receiver AV DR1401[9] has been announced. This receiver has been developed and manufactured in India and includes the full DRM feature set, i.e. with Emergency Warning Feature (EWF) support. Mass production is planned to start in August 2015. Automobile manufacturers in India have undertaken successful field trials with a view to marketing vehicles with built-in DRM receivers.

South Africa has made an extensive investigation including live transmission trials towards  making the transition to digital sound broadcasting. Live DRM test broadcasts at MF were carried out by Radio Pulpit, covering Pretoria/Johannesburg, from July 2014d until October 2015 with a mixture of programming and extra features 24 hours a day. The 10 kW DRM30 MF broadcast was on 1 440 kHz from Kameeldrift Pretoria using two types of low profile antenna. The full results of these trials are reproduced here as Attachment 1.3 to this Annex. The hundreds of thousands of measurements show better coverage than predicted over the area of Pretoria and parts of Johannesburg when using DRM30. The effect of skywave propagation were investigated, both as regards gaining more extensive coverage and assessing the amount of degradation caused by or caused to the DRM30 signal in the extended coverage zone achieved through skywave propagation at night. During the night the signal was recorded 200 km away in Gabarone, the capital of Botswana. South Africa has launched from the same site in Kameeldrift a second Digital Radio programme via DRM, "Second Channel", on 1 February 2015 carrying BBC news and extra features (i.e., RSS, Journaline, text - Pretoria News Update and BBC World Service news).

South Africa's Minister of Communications commended the trial after visit to Radio Pulpit site in June 2015 and asked for receiver manufacturing to take place in the country or the region. He affirmed that: *"I will not support the importation of these receivers from any other country outside of our Southern Africa Development Community region. Our region is very attractive and big enough for any player that would want to partner with our local manufacturers and share their skills and resources for the development of our region"*. Note that South Africa's ICT Policy Document[10] asks for simultaneous licensing of DRM and DAB services.

In Ukraine, the National Radio Company of Ukraine (NRCU) has recently announced[11] that it plans to switch broadcasting of two Ukrainian medium-wave networks to DRM. It is expected that 85-90% coverage will be achieved with around 15 new transmitters capable of digital or analogue operation. In DRM mode electricity consumption is estimated to be one third that of the current analogue medium-wave networks.

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[8] http://economictimes.indiatimes.com/industry/transportation/shipping-/-transport/road-ministry-plans-highway-radio-advisory-to-give-drivers-updates-on-traffic/articleshow/47335867.cms.

[9] See http://www.radioworld.com/article/drm-launches-india-receiver/272493.

[10] See http://www.dtps.gov.za/documents-publications/category/102-ict-policy-review-reports-2015.html.

[11] See http://radiomagonline.com/digital_radio/ukrainian_broadcaster_nrcu_drm_medium_wave_0213/.

In Denmark, the Danish public broadcaster (Denmark Radio) has purchased a high efficiency 300 kW solid-state LF transmitter in order to provide a DRM service from the 243 kHz station at Kalundborg.

## 4 Conclusions

Digital sound broadcasting is opening the door for improved or completely new broadcasting applications, including multichannel operation, bilingual educational programs and preventive warning or emergency services. This is not the radio of old but one that sits right at the heart of the connected new media space of the information society. However, given the huge base of analogue receivers in operation, the crucial question now is how to make transition to digital sound broadcasting and realise the benefits of improved audio quality and access to the wide range of service offerings now available in the audio-visual sector.

In the VHF bands, the DRM+ standard can provide the same coverage, more economically than an FM broadcasting station, by using much lower power levels. DRM+ provides other advantages over FM, with the flexibility of being able to offer a wide range of subsidiary data services, multiplexed programming or single frequency networks. DRM+ is also capable of operating in a compatibility mode in which the huge existing base of FM receivers in the home and cars can continue to be used until the audience and broadcasters can complete the changeover on the basis of mutual convenience and needs.

Moreover, DRM+ has the flexibility to satisfy any coverage need in Band II ranging from national and regional networks to community stations. DRM+ can also provide high quality broadcasting services in Band I and III, where these are not already used for TV or DAB.

In the LF, MF and HF bands, the DRM30 standard has the potential to revitalise the bands previously used for AM broadcasting. Although there are no spectrum savings *per se*, the spectrum will be used to better effect by bringing listeners reception with greater reliability and of much higher quality for all in-home, portable and in-car uses. For broadcasters, the advantages of economy and quality are particularly attractive when considering upgrading national and international AM networks. The main reason given against continuing with MF broadcasting has been the lower quality of AM. However, because most listening at MF takes place in cars, with relatively high ambient noise levels, or on portable radios with small loudspeakers, the quality issue may have been overstated. Nonetheless, a transition to DRM30, which can provide a subjective listening quality close to FM, would solve the quality issue and allowed the same coverage with a much reduced power output, thus saving energy and costs.

Moreover, both DRM30 and DRM+ can operate in a single frequency network mode in those cases where a uniform programme stream over a wide area is indeed the objective. In short, the change to DRM30 and DRM+ would make for more effective and efficient use of spectrum on several levels.

Digital sound broadcasting combines excellent audio quality with new features, such as additional data services with electronic newspapers, images and low bit video streams. All these features have already been demonstrated by DRM technology which offers the only comprehensive solution for digital sound broadcasting in all the terrestrial broadcasting bands from LF to VHF. Moreover, reception is independent of gatekeepers and third party providers like satellites, cable networks or the internet.

ATTACHMENT 1
TO ANNEX 1

# Spectrum management and service planning considerations for implementing the DRM30 system in the broadcasting bands below 30 MHz

## 1 DRM30 system characteristics

DRM provides a single common digital sound broadcasting system for national and international coverage in the LF, MF and HF bands. The system characteristics are given in Annex 1 to Recommendation ITU-R BS.1514, with more extensive details referenced in Attachment 1 therein. These meet the service requirements for digital sound broadcasting at frequencies below 30 MHz as set out in Recommendation ITU-R BS.1348, and satisfy the objectives for digital sound broadcasting in the broadcasting bands below 30 MHz set by Question ITU-R 60/6.

## 2 Spectrum management considerations

In spectrum management terms, the transition from analogue to digital broadcasting using the DRM system in the broadcasting bands would be neutral and would not of itself require additional spectrum resources or release spectrum suitable for re-engineering for other purposes.

However, there would be important benefits in being able to make more effective use of the LF, MF and HF broadcasting bands generally. This would, in principle, would allow more scope for re-using frequencies for broadcasting. The adaptability built into the DRM technology allows power levels to be matched more precisely to the service requirement than with AM. An important feature of OFDM systems, and DRM in particular, is that transmissions can co-exist with lower protection ratios than with analogue modulation. Also the power requirement for a DRM30 emission carrying the same equivalent data throughput as an AM emission is lower by a factor equating to the removal of the carrier and lower side-band – basically only the upper analogue side-band power has to be transmitted when replacing an AM emission by DRM30. A DRM30 transmission can therefore be configured so as to replicate AM coverage with an average power requirement 4 to 6 dB lower than the analogue case.

A complete transition to DRM30 in the bands allocated to the broadcasting service below 30 MHz would therefore lead to better utilization of the spectrum in terms of lower transmitter powers. Further benefits in spectrum utilization can also be realized through delivering improved audio quality and a range of added value service operations such as joint stereo and dissemination of textual and graphical data streams. However, during the transition phased of mixed analogue and digital operation, some compromises on digital coverage versus analogue audio quality may be necessary when the various protection requirements are taken into account.

## 3 Planning considerations

The planning parameters for digital sound broadcasting at frequencies below 30 MHz given in Annex 1 to Recommendation ITU-R BS.1615 shows that, in an all DRM30 environment, the protection requirements are considerably lower than for conventional AM broadcasting. The absolute co-channel protection ratio for DRM to DRM emissions are of the order of 16 dB for a bit error rate of $10^{-4}$.

This compares with the absolute value for the AM to AM co-channel protection ratio of 30 dB for a stable wanted AM signal (27 dB for a fluctuating wanted signal) in the GE75 Plan[12].

The ITU-R Circular Letter CCRR/20 condenses the comprehensive guidance provided in Annex 1 to Recommendation ITU-R BS.1615 on the planning parameters applicable to the complete range of DRM30 modulation schemes, spectrum occupancy and robustness modes, into a practical assessment of how DRM30 should be introduced into the broadcasting bands below 30 MHz. For DRM interference into wanted AM emissions, ITU-R CCRR/20 explains that the required absolute co-channel protection ratio should be 36.5 dB, meaning that that the interference potential of a DRM emission is about equal to the interference from an AM transmitter with a power 7 dB greater than the DRM transmitter.

The main consideration in re-engineering the broadcasting bands below 30 MHz is that a DRM30 transmitting station can achieve roughly equal coverage operating at powers 4 to 6 dB below the AM transmitter to be replaced, but that a power reduction of 7 dB is indicated in order to equalize the interference environment. This implies that some reduction in coverage will have to be accepted during the during the transition phase from AM to DRM. In practice, this may not prove to be a severe limitation. Because the spectrum occupancy of a DRM30 emission is virtually rectangular, with energy dispersed evenly across the entire occupied bandwidth, the 7 dB power back-off requirement can be considered as deriving from the energy throughput considerations across the channel bandwidth. However, this approach does not make use of the established methods for evaluating subjective responses to audio degradation. The interference generated by a noise-like co-channel DRM30 signal is of a very different character to the highly intrusive nature of a second (intelligible) AM service audible in the background (a technique that is recognised to be the most effective form of deliberate jamming). Nevertheless, this value of power back-off (7 dB) is currently built into the Recommendation ITU-R BS.1615.

For AM interfering with DRM30, the situation is significantly better than with any other permutation, because a well-designed COFDM receiver is able to ignore interfering AM carriers. Depending on the desired quality of service, a typical co-channel protection ratio from a co-channel AM emission into a wanted DRM30 service, delivering around 20 kb/s, is +7dB, which is at least 20 dB less stringent than the AM into AM case. Therefore, interference from existing AM stations should not disadvantage incoming DRM30 services, irrespective of whether the interference or coverage equalizing power back-off is applied.

## 4 Coverage and coding considerations in the LF and MF bands

The coverage and quality achievable with DRM30 transmissions depend primarily on the coding schemes and date rates used. In addition, broadcast planning in the LF and MF bands has to take account of the enhanced propagation that occurs during the night when the ionosphere becomes effective in reflecting the skywave component of the transmission up to several hundred km further than the surface wave component.

Long distance coverage from the skywave is subject to considerable and constant variations in signal strength, yet can still interfere with reception of other broadcasting stations within range of the skywave and can also cause self-interference over a certain range of distances – the fading zone – when the skywave signal is of similar strength to the direct surface wave signal. With AM transmissions, the resulting self-interference is characterized by rapid fluctuations and fading that can prevent any semblance of useful reception within the fading zone.

[12] NB: in the HF bands, planning for analogue broadcasting now has to be carried out on the basis of only17 dB absolute co-channel protection because of the excessive level of congestion.

Several aspects of the enhanced skywave propagation at night-time in the LF and MF bands therefore have to be considered:

a) how quality and coverage are affected during the night when skywave propagation extends the effective transmission range beyond the day-time surface wave coverage, and whether changing the DRM30 coding scheme can counter any degradations resulting from the constant fluctuations in amplitude and phase that characterize skywave propagation;

b) the extent and severity of interference to and from distant broadcasting stations, and whether the changing the DRM30 coding scheme at night can minimize the impact of skywave interference;

c) the extent and severity of degradation caused by self-interference at night in the fading zone, where the surface wave and skywave components of the wanted transmission can be received simultaneously, and whether changing the DRM30 at night can reduce the impact of self-interference.

# 5 DRM30 proof of performance trials

## 5.1 Proof of performance trial in Russian Federation using the MF band

Attachment 1.1 provides proof of performance trials on DRM30 carried out in the vicinity of Moscow. The main test objectives were in determining more accurate DRM30 signal parameters for planning of DRM30 networks in the medium–frequency band in similar geophysical environments.

In particular, the test objectives included:

a) Assess the DRM30 signal reception in the MF band in the urban and rural areas.

b) Determine the reliable reception area for DRM30 signal.

c) Study on the possibility of DRM30 signal reception over the ground–wave and sky–wave paths and in the fading zone.

d) Measure the DRM30 signal parameters in the reception areas (field strength, signal–to–noise ratio, percentage of decoded audio frames).

The coverage and quality assessments reported in Attachment 1.1 for a DRM30 MF broadcasting station established near Moscow supplement the findings of previous DRM30 trials at MF, particularly as regards how the natural day and night variations in propagation conditions need to be addressed when planning DRM30 services. The results of these trials and measurements are summarized below.

### 5.1.1 Day-time coverage

Comparison of DRM30 coverage and quality with a representative AM transmission, having a daytime service area of 75 to 90 km (specified SNR = 26 dB and 30% modulation), shows that DRM30 transmissions running at half the power of the AM transmission typically can deliver subjective audio quality matching “VHF FM stereo” over an area ~4 times larger than in the AM mode (distances of 120 to 180 km) using the 64QAM(3) mode or quality close to VHF FM over an area ~9 times larger (distances of 220 to 260 km) using the 64QAM(0) mode.

### 5.1.2 Night-time coverage

Comparison of DRM30 coverage and quality with a representative AM transmission, having a night-time service area up 150 km (specified SNR = 8 to 12 dB with audible fading and 30% modulation), shows that DRM30 transmissions running at half the power of the AM transmission typically can deliver subjective audio quality matching “VHF FM stereo” out to distances of 75 to

90 km using the 64QAM(3) mode or quality close to VHF FM out to distances of 150 to 200 km ) using the 64QAM(0) mode.

#### 5.1.3 Fading zone coverage

Conditions in the fading zone are particularly difficult to assess because the same DRM30 signal is interfering with a time delayed version of itself. The DRM30 specification provides for two interference immunity modes (A and B) within in the various coding schemes available. The measurements showed immunity mode “A” performed consistently better with several coding schemes - fortunate outcome since a higher data rate is available with mode “A”.

### 5.2 Proof of performance trial in the Russian Federation using a single frequency network at HF

Attachment 1.2 provides a proof of performance trial relevant to the option in the DRM standard [1] to deploy a single frequency synchronous broadcasting network. Trials have previously been carried out in the MF broadcasting band in Berlin [2], in the HF bands in in Western Europe [3] and in the 26 MHz band in Moscow.

However, although trials produced data on the successful applications of the concept there was still a lack of detailed quantitative data describing the use of synchronous networks. In order to gather better information, the combined effect of HF transmissions from Krasnodar and Kaliningrad, over paths of around 1 000 km, into the planned reception zone in the Moscow region were assessed. The main objective of these trials was to provide guidance on the optimum choice of parameters for the successful implementation of a synchronous DRM30 broadcasting network at HF. An assessment is also provided of the net enhancement achievable through using a synchronous network, i.e., gains, which can ensured by a synchronous network compared to separately operating transmitters within the spatial wave coverage.

The main finding was that a substantial improvement in network gain is achievable – typically 6 dB or more depending in receiving antenna – with fewer deep fades through making an informed choice of transmission parameters.

### 5.3 Proof of performance trial in South Africa using the MF band

Attachment 1.3 provides proof of performance trials on DRM30 carried out in the greater Pretoria area and the northern parts of Johannesburg.

## 6 Conclusions

Re-engineering the MF broadcasting bands for use by the DRM30 DSB system can offer larger coverage with better quality of audio content with lower transmitter powers than traditional AM broadcasting, while achieving a quality of service comparable to VHF FM. Moreover, self-interference effects from skywave reception in the fading zone can be overcome by selecting the coding scheme and immunity mode that is best suited to the prevailing conditions.

A complete transition to DRM would allow for more effective and intensive use the broadcasting bands below 30 MHz compared to AM. This would certainly be the case in the LF and MF bands.

Unfortunately, matters are not so straightforward in the HF bands where seasonal planning for analogue HF broadcasting now has to be carried out on the basis of only17 dB (instead of 30 dB) absolute co-channel protection because of the excessive level of congestion in many of the HF broadcasting bands. Thus, any potential benefits in terms of better spectrum occupancy through a transition to digital modulation in the HF broadcasting bands have already been absorbed by the present level of congestion. If the spectrum demand in the HF broadcasting bands then increases as a result of the higher quality of service possible with DRM30, then a choice will again have to be made on whether to sacrifice quality for quantity.

Overall, the combination of OFDM/QAM techniques used in DRM offers close to the maximum theoretical spectral efficiency. Moreover, DRM offers important benefits in spectrum utilization through being able to replicate analogue coverage at average power levels at least half of that required by conventional AM broadcasts, as well as being able to provide a wide range of added value services.

*[Editorial note: Former Attachments 2.1 and 2.1bis were relocated here as Attachments 1.1 and 1.2 without change.]*

ATTACHMENT 1.1
TO ANNEX 1

## Measurements of DRM30 coverage area in the medium–frequency band in the day–time, night–time and in the fading zone

## 1 Introduction

Results of the DRM30 system implementation studies carried out over during several years were presented in Report ITU–R BS.2144 and Recommendation ITU–R BS.1615. These documents played an important role in the practical implementation of DRM broadcasting. However, with attention now turning to the wide scale implementation of DRM30 service, the progress achieved recently in this field also needs to be reflected.

Additional measurements are presented here that provide data on the estimated minimum field strengths, signal–to–noise ratios (SNR), percentage of decoded audio frames and other parameters which are essential for ensuring that satisfactory DRM30 reception quality is achieved in practical DRM30 implementations.

The measurements here were carried out in the medium–frequency (MF) band over moderately rugged terrain, covering both urban and rural areas, and include variations in night–time and day–time coverage and quality, as well as in the fading zone.

**Test objectives:**

a) Study of the DRM30 signal reception in the MF band in the urban and rural areas.

b) Determination of the reliable reception area for DRM30 signal.

c) Study on the possibility of DRM30 signal reception over the ground–wave and sky–wave paths and in the fading zone.

d) Measurements of DRM30 signal parameters in the reception areas (field strength, signal–to–noise ratio, percentage of decoded audio frames).

The main test objective was determination of the more accurate DRM30 signal parameters for planning of DRM30 networks in the medium–frequency band in similar geophysical environments.

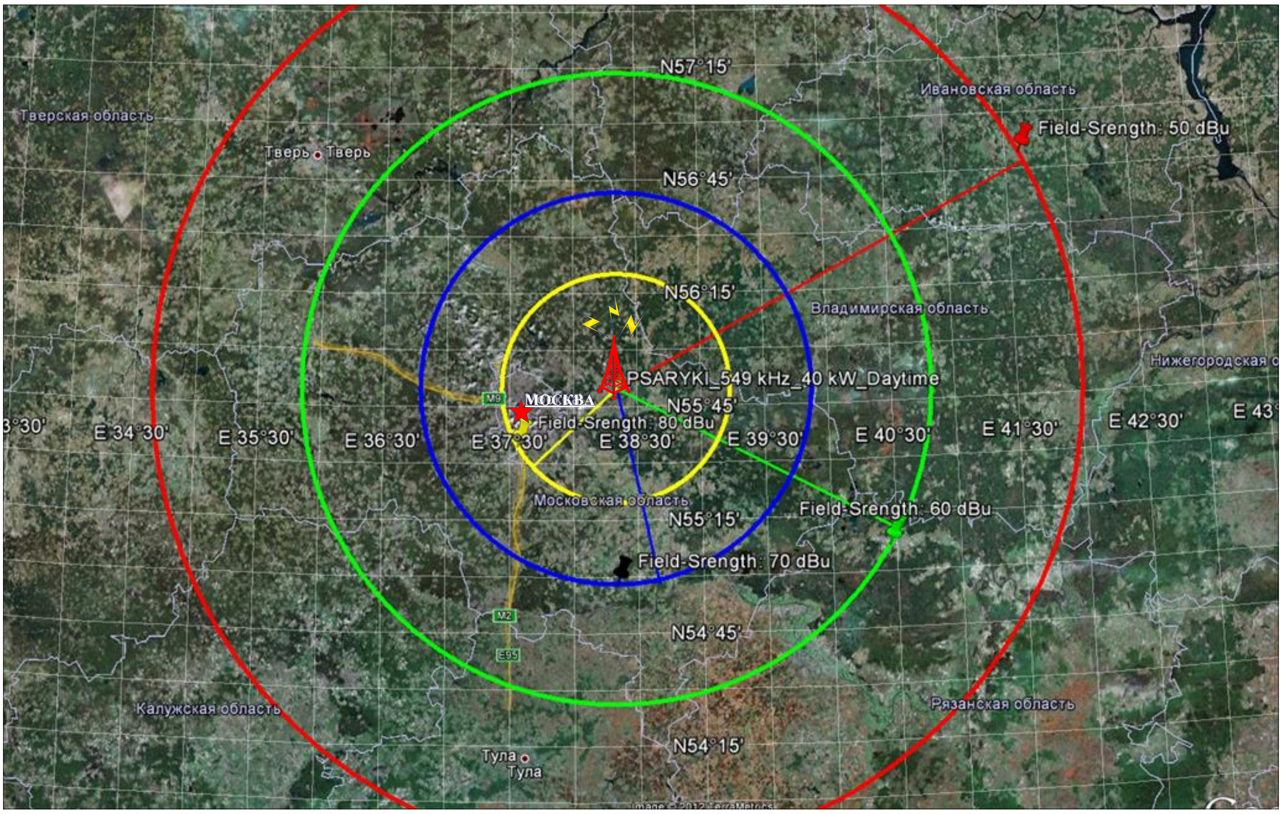
## 2 Test conditions

The medium wave DRM30 transmitter was installed at the radio broadcasting centre approximately 40 km from the centre of Moscow. Locations of the transmitter and the fixed measuring site, as well as paths for mobile measurements are shown in Fig. 4. Configuration and technical characteristics of the transmitting equipment are shown in Table 6. Configuration of the receiving equipment is shown in Table 7.

Expected field strength for different distances from the transmitter (Fig. 3) in the day–time, required for the preliminary determination of the service area, was calculated using software «LFMFPLOT», (software product of MICRODATA company). The Earth conductivity was assumed to be 3 mS/m and dielectric permittivity of 10.

FIGURE 3

**Calculated contours of the ground–wave field strength**




**Calculated data:** **240 km (50 dBu);** **150 km (60 dBu)**
**100 km (70 dBu);** **60 km (80 dBu)**

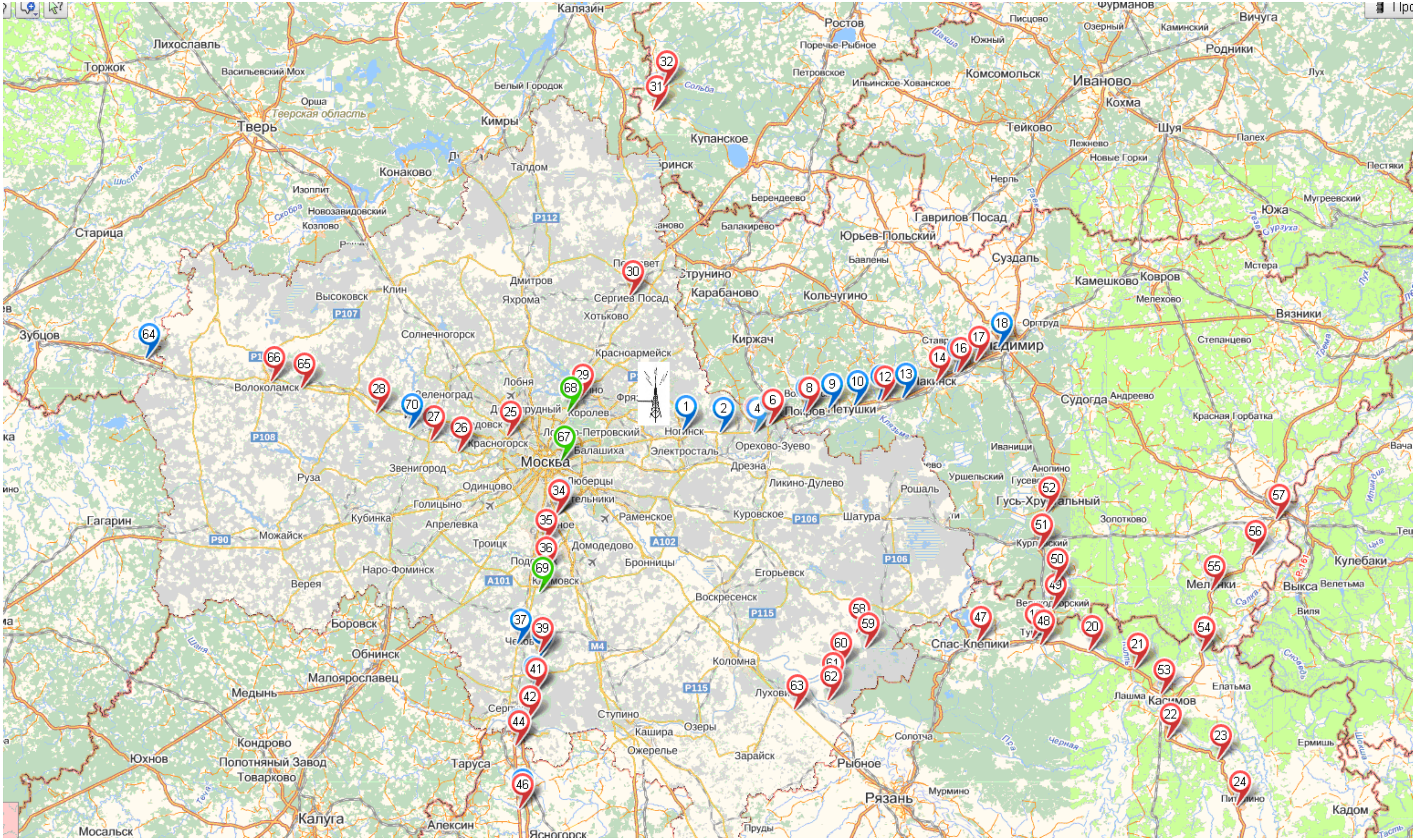
Figure 3 shows that the predicted ground–wave field strength in day–time is 80 dBμV/m at distance of 60 km (urban reception is possible); 70 dBμV/m at 100 km (guaranteed reception in rural area); 60 dBμV/m at 150 km (reliable reception not at all locations and unguaranteed 98% decoding throughout a year); 50 dBμV/m at 240 km (reception at separate “quiet” locations and without guaranteed 98% decoding throughout the year). In the North–West direction at the edge of the service area, co–channel interference from the transmitter (549 kHz, located at 625 km) is possible.

According to the calculations, radial directions for measurements were chosen to be East, West, North, South and South–East from the transmitter, as well as South–East direction to assess field strength place–to–place variations at the distances 110 km, 150 km and 220 km from the transmitter. As a fixed reception site the following sites were equipped: Moscow City site (megalopolis area), Mytishchi site (suburban town of Moscow – urban area) and radio receiving centre at 30 km from the Moscow City border (rural area).

Locations of receive measurement positions are shown on the map in Fig. 4. Data were measured in the daytime (red marks) and in the night–time (blue marks) in the radial directions from the transmitter (East, West, North, South and South–East) and in the South–East direction at 110 km, 150 km and 220 km from the transmitter, as well as in the fixed receive positions (green marks). Some marks of night–time and daytime measurements at the same position are overlapped.

FIGURE 4

**The map of receive measurement positions**



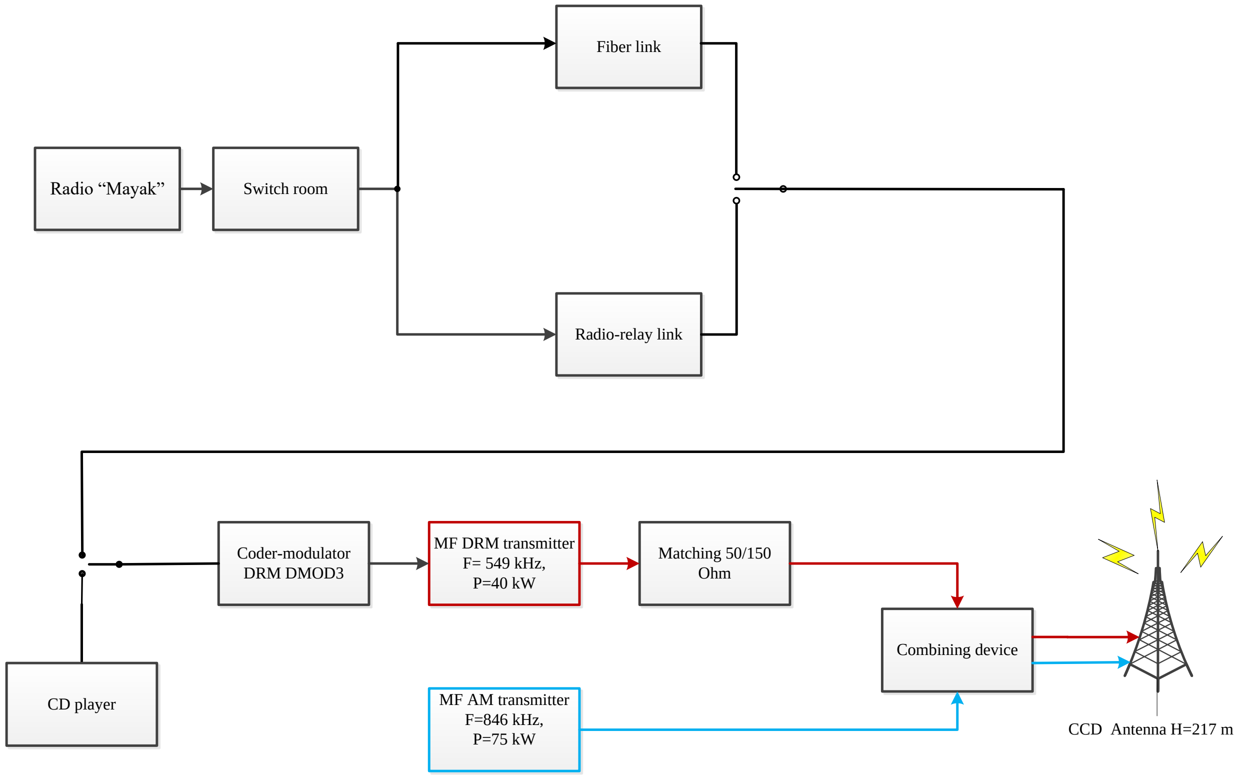
# 3 Configuration and technical characteristics of the transmitting equipment

TABLE 6

| | |
|---|---|
| Transmitter | MF, DRM30, P = 40kW (Fig. 5) |
| Coordinates of Radio broadcasting centre | 55.50.10N; 38.20.35E |
| Sound signal source | “Mayak” radio programme, CD player |
| Frequency | 549 kHz |
| Bandwidth | 9 kHz |
| Antenna system | Antenna mast with controlled current distribution (CCD),<br>Antenna height=217 m (Fig. 6) |
| **Auxiliary equipment** | |
| CD player | Set of test CDs (tone signals, selection of musical samples with different frequency spectrum and dynamic range) |
| Sound processor | ORBAN 2200 FM (stereo) |

FIGURE 5

**Block diagram of the transmitting equipment**



# 4 Configuration of the receiving equipment

TABLE 7

| Fixed measuring equipment | Mobile measuring equipment |
|---|---|
| Fraunhofer DRM Monitoring Receiver DT700 | Fraunhofer DRM Monitoring Receiver DT700 |
| Notebook + appropriate software (Dream, Neutrik Audio Test & Service System A1) | Notebook + appropriate software (Dream, Neutrik Audio Test & Service System A1) |
| SMV–6.5 Set of calibrated antennas<br>Antenna installation height 1.5 m from the ground level | SMV–6.5 Set of calibrated antennas<br>Antenna installation height 1.5 m from the ground level |
| Consumer receivers: Himalaya, Richardson | Consumer receivers: Himalaya, Richardson, Roberts |

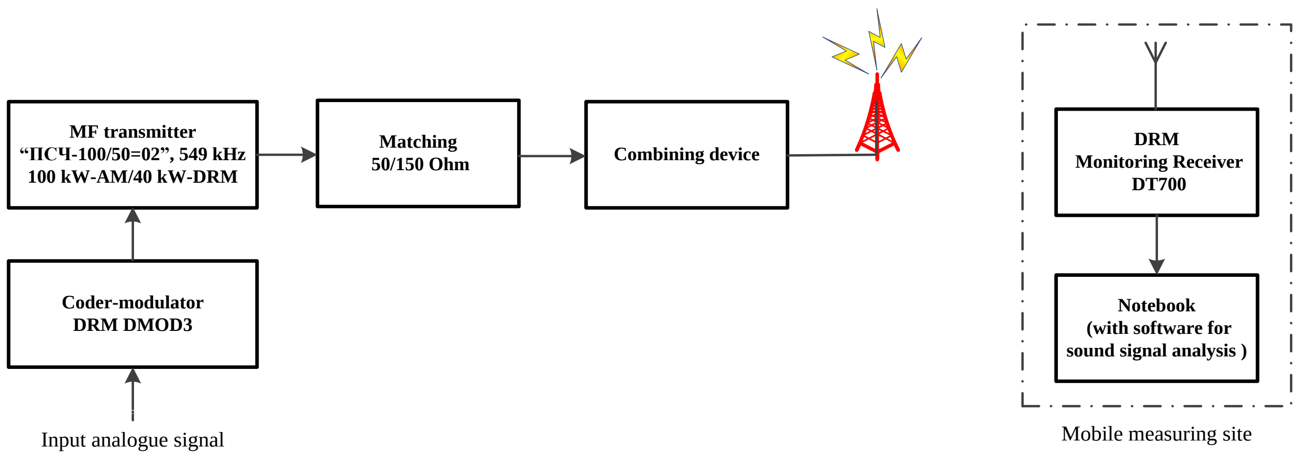
# 5 Methodology of field strength measurement

During the measurement, the transmitter was switched to the corresponding transmission mode (DRM30 or AM) without modulation by sound signal and with nominal radiated power.

Signal field strength at the reception position was measured using Fraunhofer Monitoring Receiver DT700 and the calibrated measurement antenna of magnetic type according to the block diagram shown in Fig. 6.

FIGURE 6

**Block diagram for measurement of field strength and parameters of the transmitted signal (Mobile measuring site)**




Description of measurements:

a) the measuring antenna was located at the distance of two to three metres from the automobile and other reflecting metal objects. Measurements were not allowed close to electric power lines;

b) connecting cable between the measuring antenna and the Fraunhofer Receiver DT700 had characteristic impedance of 50 Ohm;

c) Fraunhofer Receiver DT700 performed relevant measurements at every measurement position;

d) field strength levels were read from the display of the Fraunhofer Receiver DT700.

Field strength was calculated using the following formula:

$$E\ [\mathrm{dB\mu V/m}] = U\ [\mathrm{dB\mu V}] + K\ [\mathrm{dB/m}]$$

where:

U[dBμV] : voltage level measured by the Fraunhofer Receiver DT700;

K = XX [dB/m]: conversion (transformation) coefficient for the measurement antenna, which is derived from the calibration curves for the specified operating frequency.

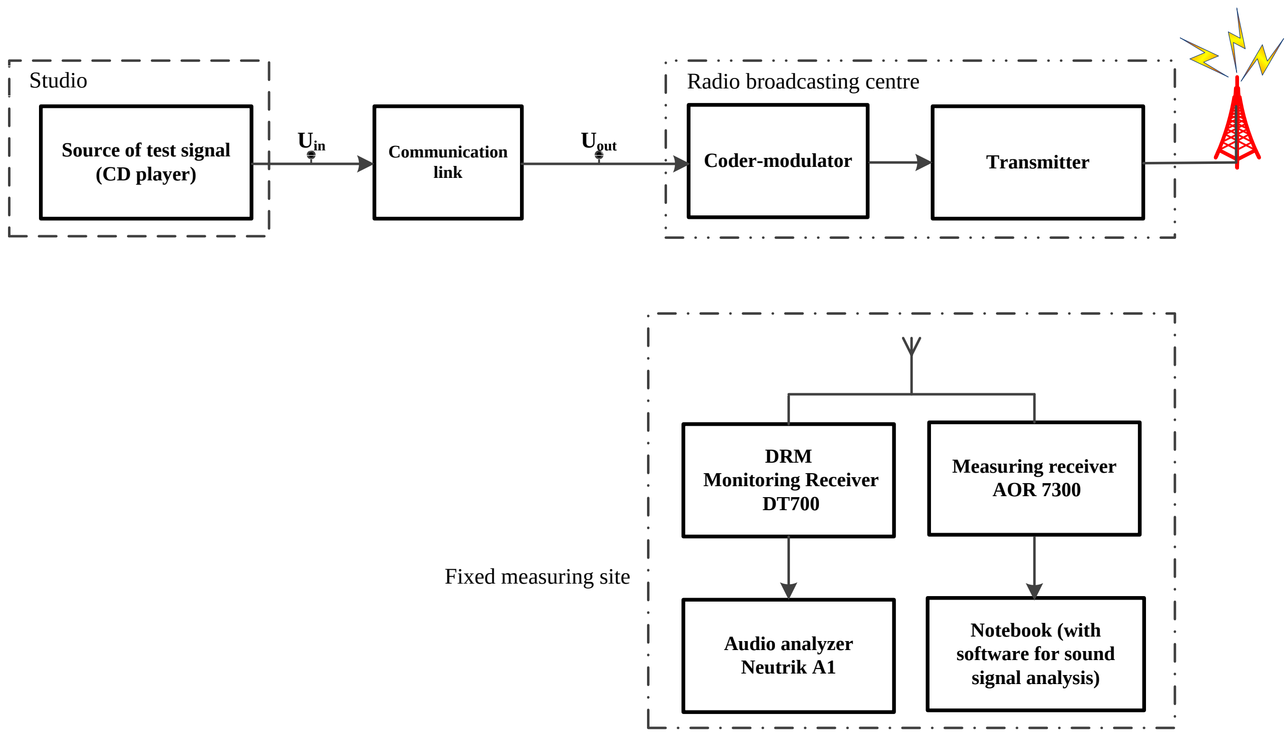
Signal–to–noise ratio (SNR) for the received DRM30 signal was measured simultaneously with the field strength measurement.

Simultaneously with these measurements, an additional auditory monitoring was performed to reveal short–time loss of the received sound signal.

Signal parameters in fixed reception positions were measured according to the block diagram shown in Fig. 7.

FIGURE 7

**Block diagram for measurement of field strength and signal parameters (Fixed measuring site)**




## 6 Measurement of coverage areas for DRM30 and AM broadcasting

### 6.1 Measurements in the day–time

Measurement results for the field strength and SNR in the day–time are shown in Fig. 8. Legend in the figure: E – East, N – North, S – South, W – West, SE – South–East. Threshold values for a surface wave are also shown for 100% decoding in the 64QAM(3), 64QAM(0) and 16QAM(0) modes.

Figures 8 and 9 show threshold values as “Better than VHF–FM”, “Close to VHF–FM” and “Close to AM”. These threshold values were chosen based on the conditions that:

a) data rate with 64QAM (3) is 34 680 kbit/s, so the playback bandwidth is 16 700 Hz, that is “Better than VHF–FM”;

b) data rate with 64QAM (0) is 22 060 kbit/s, so the playback bandwidth is 12 700 Hz, that is “Close to VHF–FM”;

c) data rate with 61QAM (0) is 10 980 kbit/s, so the playback bandwidth is 2 800 Hz, that is “Close to AM”.

Based on the measurement results for the field strength, it is possible to select the most appropriate values of effective specific conductivity and dielectric permittivity of the Earth surface for the current season, that is 1.5 mS/m and 20, accordingly (red curve in Fig. 8). For the 64QAM(3) mode, 100% decoding of the audio signal was possible at the distances 120 to 180 km from the transmitter (depending on the direction). In the North and West directions this distance corresponded to the minimum, i.e. 120 km, which can be explained by the following reasons:

a) co–channel interference from the transmitter located in the area of St. Petersburg;

b) field strength attenuation along the path over Moscow (West) or over the Klinsko–Dmitrovskaya Gryada (North).

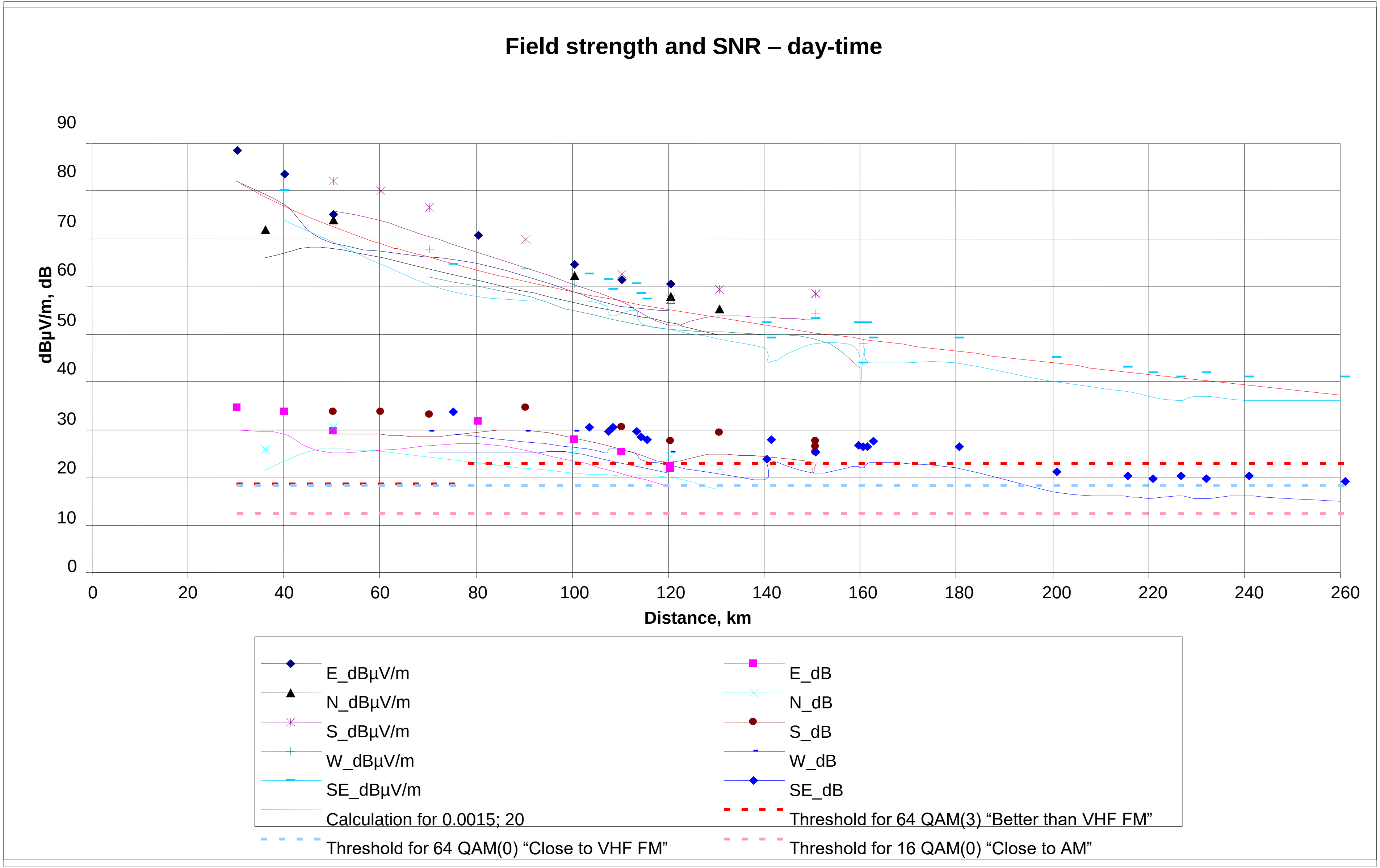
100% decoding in this mode was observed in the South direction at the distance of up to 150 km and in the South–East direction at the distance of up to 180 km.

Measurements in positions 47, 48, 49, 50, 51, 52 (see Fig. 4) located at the distance from 140 to 160 km from the transmitter at the length of 84 km in the South–East direction demonstrated reliable decoding in the 64QAM(3) mode with variation of field strength up to 8dB from place to place.

In the 64QAM(0) mode, 100% decoding of the audio signal in the South–East direction was observed at the distance of up to 260 km from the transmitter, positions 22, 23, 24 (see Fig. 4). Measurements in positions 53, 54, 55, 56, 57 (see Fig. 4) located at the distance of 220 km in the South–East direction demonstrated reliable decoding in the 64QAM(0) mode with insignificant variations of the field strength from place to place.

FIGURE 8

**Field strength and SNR in the day–time**



In the AM mode, radius of the service area was 75 to 90 km (SNR = 26 dB with 30% modulation). At the distance of 160 km from the transmitter, SNR = 13.4 dB in the AM mode.

Thus, the service area in the DRM30 64QAM(3) mode (quality “better than VHF FM stereo”) is 4 times larger than in the AM mode, but using only half the power for the DRM30 transmission.

The service area in the DRM30 64QAM(0) mode (quality “close to VHF FM”) is 9 times larger than in the AM mode, but using only half the power for the DRM30 transmission .

## 6.2 Measurements in the night–time and in the fading zone

Measurement results for the field strength and the SNR in the night–time are shown in Fig. 9. Legend in the figure: E – East, S – South, W – West. Threshold values are also shown for 100% decoding for the combination of the ground wave and the ionospheric wave in the 64QAM(3), 64QAM(0) and 16QAM(0) modes, as well as calculated curves for field strength of the surface wave (red colour) and the ionospheric wave (green colour). Field strength of the ionospheric wave is calculated according to [3].

In the 64QAM(3) mode, 100% decoding of the audio signal was possible at the distance of 70 to 80 km from the transmitter (depending on the direction) with the surface wave prevailed.

Reliable reception of the skywave was observed at distances greater than 200 km in the 64QAM(0) mode.

In the AM mode at the distance of 150 km from the transmitter, SNR was 8 to 12 dB with aurally noticeable fading.

The fading zone existed at distances from 80 to 120 km for the given transmitter with the given antenna at the frequency of 549 kHz, and reception in this zone was studied in more detail.

One of the study objectives was the practical assessment of the preference between two interference immunity modes, "A" or “B”, for use in the fading zone in the night–time. The relevance of this objective can be shown by means of the following arguments.

It is known that the DRM30 standard [1] recommended use of interference immunity mode “B” with the duration of the guard time of 5.33 ms (“A” mode uses 2.66 ms) in the MF band in the night–time. The propagation channel model for this case (channel No.2, combination of the ground wave and ionospheric wave) comprises two beams with the propagation delay of only 1 ms.

SNR required for decoding in the propagation channel model No.2 in the “B” mode is somewhat higher than in the “A” mode.

Digital bitrates available in the “A” mode are significantly higher than in the “B” mode. With 10 kHz bandwidth and 64QAM modulation, this allows quality of sound “close to VHF FM” (22.1 kbit/s) or “like VHF FM” (26.5 kbit/s) with code rates of 0.5 and 0.6. For these cases required SNRs at the receiving position are 14.9 dB and 16.3 dB accordingly.

In the “B” mode, comparable quality of sound requires code rates of 0.6 (20.1 kbit/s) and 0.71 (24.7 kbit/s), and this needs SNRs of 16.9 dB and 19.7 dB at the receiving position, i.e. 2 to 3 dB higher than in the “A” mode.

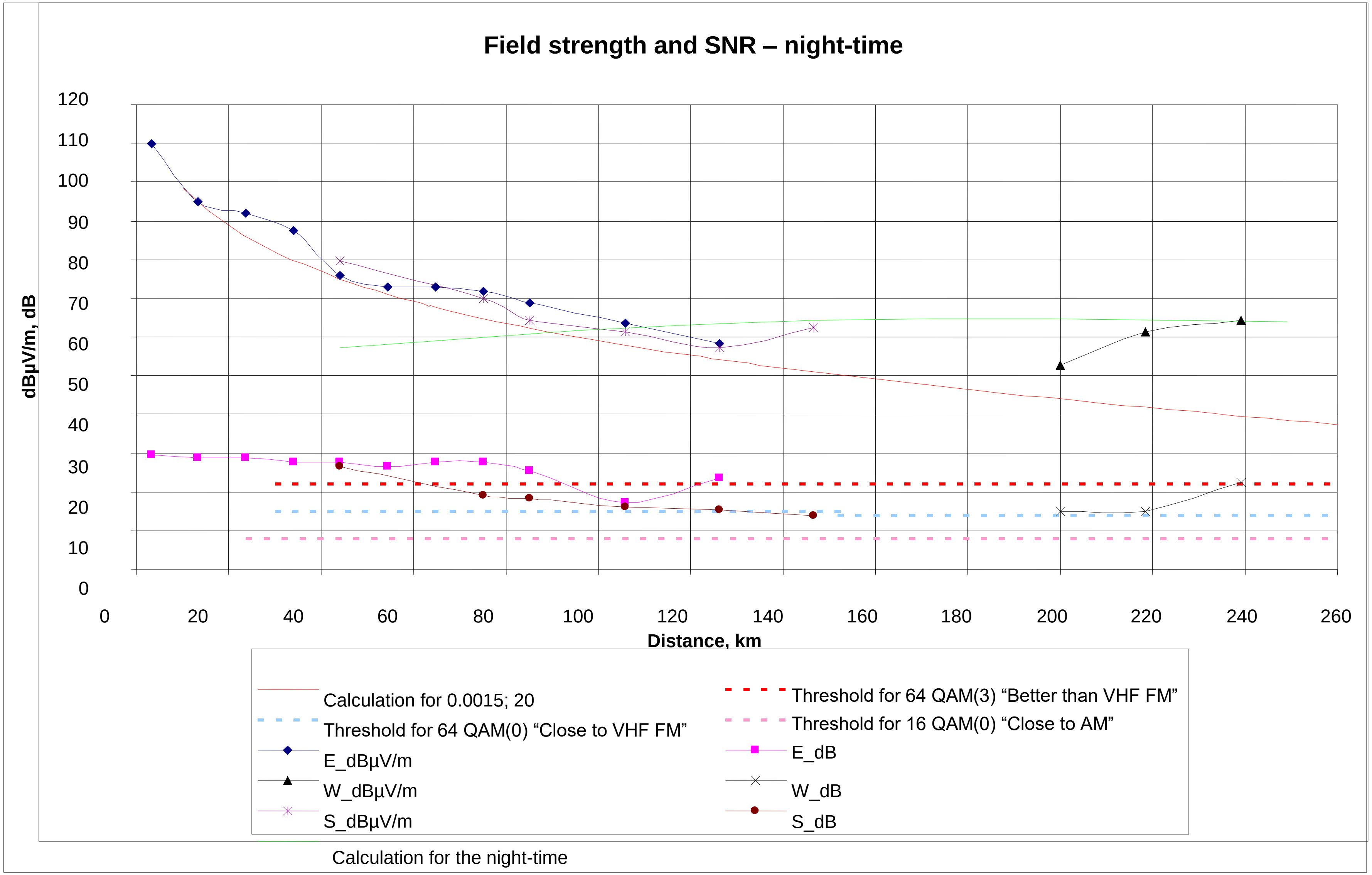
Additionally, signal reception in the MF band in the night–time is generally complicated by the presence of co–channel interference from remote stations. In the presence of the co–channel interference, absolute protective ratio for the “A” mode with 10 kHz bandwidth and 64QAM(1) modulation is 6.7 dB, and for the “B” mode with similar parameters it equals 7.3 dB [4].

According to [4], at frequencies below 700 kHz and at distances of 100 to 200 km, arrival of waves having relevant intensity for decoding and delayed for more than 2 ms relative to the ground wave is not predicted. For this reason it can be suggested that using the interference immunity “A” mode in the above conditions with comparable quality of sound will be more power efficient than using the “B” mode.

For practical verification of the above argumentation, measuring position was chosen at the distance of 97 km from the transmitter, where the field strengths of the surface wave and the ionospheric wave were about the same. This parity is verified by the fact that the depth of fading with AM signal was significant and reached 14 dB.

FIGURE 9

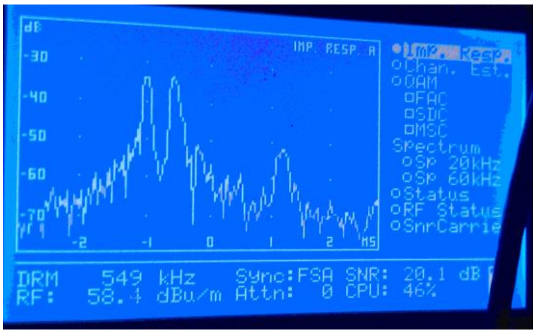
**Field strength and SNR in the night–time**

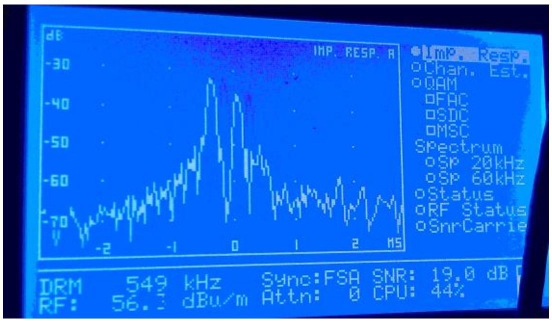


Illustrations of the DRM30 signal reception in the fading zone are shown in Fig. 10. One of the illustrations for impulse response of the channel demonstrates equal surface and ionospheric waves with the delay of about 0.4 ms between them. The ionospheric wave is time–variant. Other waves with longer delays have significantly smaller strength. Image of transfer function of the channel, similarly to the "SNR spectrum", resembles frequency–selective fading.

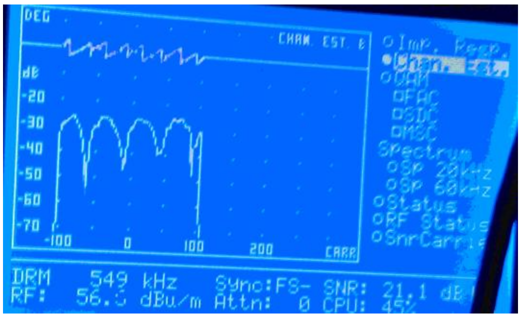
FIGURE 10

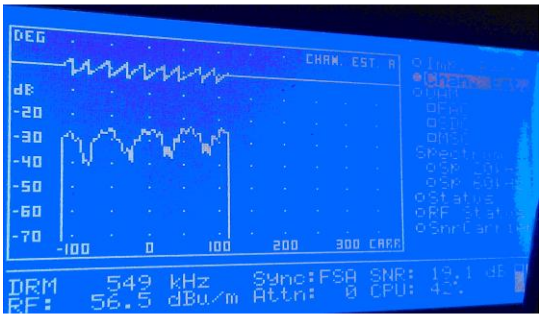
**Illustrations for the reception of the DRM30 signal in the fading zone**




Examples of impulse response of the channel in the DRM30 mode

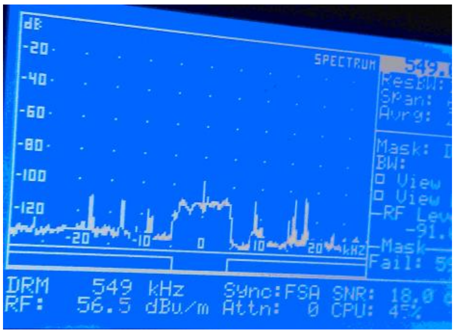



Examples of transfer function of the channel in the DRM30 mode



Examples of "SNR spectrum" – SNR values for subcarriers



Spectrum of input signal in the 60 kHz bandwidth

At the central frequency of the desired signal spectrum, interference is observed with field strength (measured in the absence of the wanted signal) equal to 40…44…47 dBµV/m, received from AM broadcasting station (Germany) operating at the co–channel carrier frequency (549 kHz). The field strength of the wanted signal was 54…58 dBµV/m, and required protection ratios were met for protection level (1), but for protection levels (2) and (3) they could be violated with the growth of interference level and attenuation of wanted signal.

Thus, the performed measurements correspond to the actual interference environment "at the border of possible reception area" and allow comparing the interference immunity of "A" and "B" modes.

To perform this comparison, "A" and "B" immunity modes alternatively changed code rates, and RSCI files were recorded for each fragment with a subsequent calculation of percentage of correctly decoded audio frames. Recall that according to the international practice, "operability" of DRM30 broadcasting is determined by the "98% of decoded audio frames" criterion. The measurement results are shown in Table 8.

TABLE 8

**Percentage of correctly decoded audio frames for different immunity modes**

| **Immunity mode/ code rate** | **"A"** | **"B"** |
|---|---|---|
| 64QAM(0) | 100% | 100% |
| 64QAM(1) | 100% | 100% |
| 64QAM(2) | 99.93% | 97.68% |
| 64QAM(3) | 97.49% | 63.27%<br>90.21% |

Table 8 shows that with 10 kHz bandwidth, 64QAM(0) and 64QAM(1) both immunity modes ("A" and "B") demonstrated 100% decoding.

For 64QAM(2) and 64QAM(3) modes having almost equal field strength of the wanted signal, "A" mode provided higher percentage of decoded audio frames.

Hence, the experimental studies showed that "A" mode had higher interference immunity than "B" mode in the above conditions.

Taking into account that in the "A" mode a higher data rate is available, and that in order to achieve the same quality of sound content transmission, a lower code rate could be used requiring lower SNR for decoding, "A" mode of interference immunity is recommended for use in the MF band in the night–time at operating frequencies below 700 kHz.

This Recommendation will allow extending the service zone of the surface wave (which is reduced in the night–time due to the increase of the noise level) by the size of the fading zone.

## 7 Fixed reception in rural, urban and megalopolis areas

Fixed reception was performed in the following positions:

– Lvovsky township in the Moscow Region (rural area, 77 km from the transmitter, see Fig. 4, position 69).

– Mytishchi town of the Moscow Region (urban area, 40 km from the transmitter, see Fig. 4, position 68).

– Moscow City, Aviamotornaya street (megalopolis area, 40 km from the transmitter, see Fig. 4, position 67).

During these tests the receiving equipment was installed indoors. Power supply was delivered by electric power network and batteries. Electric lights and computers were turned on in the rooms.

Measurements were performed using 4.5, 5.0, 9.0 and 10.0 kHz bandwidths, the "A" mode, 16QAM and 64QAM modulations with all available levels of interference immunity. Measurement results for the field strength and the SNR are shown in Tables 9, 10, 11.

TABLE 9

**Measured data (rural area)**

| No. | Bandwidth (kHz) | Field strength (dBμV/m) | Signal–to–noise ratio (dB) |
|---|---|---|---|
| 1 | 4.5 | 62 | 30.9 |
| 2 | 5 | 62 | 30.2 |
| 3 | 9 | 63.8 | 27.4 |
| 4 | 10 | 63.5 | 26.9 |

TABLE 10

**Measured data (urban area)**

| No. | Bandwidth (kHz) | Field strength (dBμV/m) | Signal–to–noise ratio (dB) |
|---|---|---|---|
| 1 | 4.5 | 80 | 34 |
| 2 | 5 | 80 | 32.5 |
| 3 | 9 | 80 | 30 |
| 4 | 10 | 80 | 29 |

TABLE 11

**Measured data (megalopolis area)**

| No. | Bandwidth (kHz) | Field strength (dBμV/m) | Signal–to–noise ratio (dB) |
|---|---|---|---|
| 1 | 4.5 | 74 | 27.3 |
| 2 | 5 | 74 | 27.1 |
| 3 | 9 | 77 | 25.7 |
| 4 | 10 | 76.2 | 25.1 |

Measurements showed 100% decoding of the DRM30 signal using consumer and monitoring receivers for all used operating modes of the DRM30 modulator.

In the AM mode in the megalopolis fixed position at the distance of 40 km from the transmitter, SNR value was 23 dB, with specified SNR = 26 dB and 30% modulation. Thus, at the distance of only 40 km from the transmitter, in the Moscow City there is no reception of AM signal with the specified quality, but the DRM30 signal is received with the quality comparable to VHF broadcasting.

Additionally, it should be noted that in the environment with industrial and typical household interference which is always presented in living quarters (especially urban), reception using magnetic type antenna is more efficient than reception using rod antenna. This is due to the fact that in the electromagnetic field of this interference type, electric component prevails, and magnetic type antenna is not sensitive to the electric component.

## 8 Assessment

The following conclusions are made based on the analysis of the measured test data in the DRM30 broadcasting pilot zone in the MF band:

a) In the day–time:

- – in the AM mode, radius of service area was 75 to 90 km (specified SNR = 26 dB with 30% modulation);
- – in the 64QAM(3) mode, 100% decoding of the audio signal was possible up to distances of 120 to 180 km from the transmitter (depending on the direction). Measurements at distance of 150 km from the transmitter in the South–East direction showed 100% decoding with field strength variations up to 8dB from place to place. Service area in the DRM30 64QAM(3) mode (quality "better than VHF FM stereo") is 4 times larger than in the AM mode, but using only half the power for the DRM30 transmission;
- – in the 64QAM(0) mode, 100% decoding of the audio signal in the South–East direction was observed at distance of up to 260 km from the transmitter. Measurements in the positions at the distance of 220 km from the transmitter in this direction showed reliable decoding with insignificant field strength variations from place to place. Service area in the DRM30 64QAM(0) mode (quality "close to VHF FM") is 9 times larger than in the AM mode, with DRM30 transmission.

b) In the night–time:

- – in the AM mode at the distance of 150 km from the transmitter, SNR value was 8 to 12 dB with audible fading;
- – in the 64QAM(3) mode, 100% decoding of the audio signal was observed up to distances of 70 to 90 km from the transmitter (depending on the direction) with the prevalence of the surface wave. At distances less than 150 km, 100% decoding of the audio signal was possible in the 64QAM(0) mode. At distances greater than 200 km, reliable reception of the sky–wave (ionospheric wave) was observed in the 64QAM(0) mode.

In the fading zone at distances from 80 to 120 km for the given transmitter with the given antenna at the frequency of 549 kHz, the analysis showed that:

- – 100% decoding was observed with 10 kHz bandwidth, 64QAM(0) and 64QAM(1) modulations for both ("A" and "B") interference immunity modes;
- – in 64QAM(2) and 64QAM(3) modes having almost equal field strength of wanted signal, "A" mode provided higher percentage of decoded audio frames;
- – in the reviewed conditions, "A" mode provides higher interference immunity than "B" mode;

– taking into account that in the “A” mode a higher data rate is available, “A” mode could be recommended for use in the MF band in the night–time at operating frequencies below 700 kHz. This recommendation will allow extending the service area, which is decreasing in the night–time due to the growth of the noise level, by the size of fading zone.

Overall, the studies showed that the DRM30 broadcasting provides larger coverage with better quality of audio content with lower transmitter power than traditional AM radio broadcasting.

**References**

[1] ETSI ES 201 980v4.1.1 (2014–01) Digital Radio Mondiale (DRM); System Specification.

[2] GOST R 51742–2001. Broadcasting transmitters, fixed AM modulated, ranges of low frequency, mean frequency and high frequency. Main parameters, technical requirements and methods of measurement.

[3] Recommendation ITU–R P.1147 – Prediction of sky–wave field strength at frequencies between about 150 and 1 700 kHz.

[4] Recommendation ITU–R P.1321 – Propagation factors affecting systems using digital modulation techniques at LF and MF.

[5] Recommendation ITU–R BS.1615 – Planning parameters” for digital sound broadcasting at frequencies below 30 MHz.

ATTACHMENT 1.2
TO ANNEX 1

## Single Frequency DRM30 Radio networks in the HF bands

## 1 Introduction

The DRM standard [1] envisages the option of applying single frequency synchronous broadcasting networks. Tests have been carried out in the MF broadcasting band in Berlin [2], in the HF bands in in Western Europe [3] and in the 26 MHz band in Moscow.

Despite the successful trial data, there is no detailed quantitative data describing the use of synchronous networks in the available literature. Guidance is therefore provided here on optimum choice of parameters for the successful implementation of a synchronous DRM standard digital broadcasting network at HF. An assessment is also provided of the net enhancement achievable through using a synchronous network, i.e. gains, which can ensured by a synchronous network compared to separately operating transmitters within the spatial wave coverage.

## 2 Description of test terms and conditions

Tests of parameters of synchronous DRM standard digital broadcasting SW networks required a number of (at least two) transmitting systems, which could at one frequency in the planned service area create sufficient to decode, approximately equal (up to 10 dB) field strengths for a sufficiently long time. If the difference in field strengths generated by each transmitter is more, it will be almost equivalent to the case of receiving the signal from a more powerful transmitter.

Thereafter, the transmitters in Krasnodar with capacity 30 kW DRM–mode antenna AHR 4/2/0.5 with an azimuth of 337 degrees and 15 kW power in Kaliningrad with AHR 1/1/0.5 with an azimuth of 40 degrees were chosen. These transmitters were located at a distance of some 1000 km from the planned zone in Moscow region.

To select frequency ranges and working the "ITS HF Propagation" package "ICEPAC" program was used. Transmitter frequencies within the range 9.7 MHz for day time and in the range of 7.2 MHz for night–time were selected.

Figure 11 illustrates the calculated field strength within 24 hours for the various frequencies in the proposed service area at the point of measurement of the Krasnodar transmitter, and Fig. 12 demonstrates that from the Kaliningrad transmitter.

In general, synchronous network coverage area should be regarded as overlapping of the zones with the required tension fields and areas with the presence of synchronism.

According to calculations, simultaneous reception is in the vicinity of Moscow most of the daytime; therefore Moscow region was used as the receiving location.

FIGURE 11

**Calculated field strength (within 24 hours) for the various frequencies in the measuring point in the Moscow region of Krasnodar transmitter**

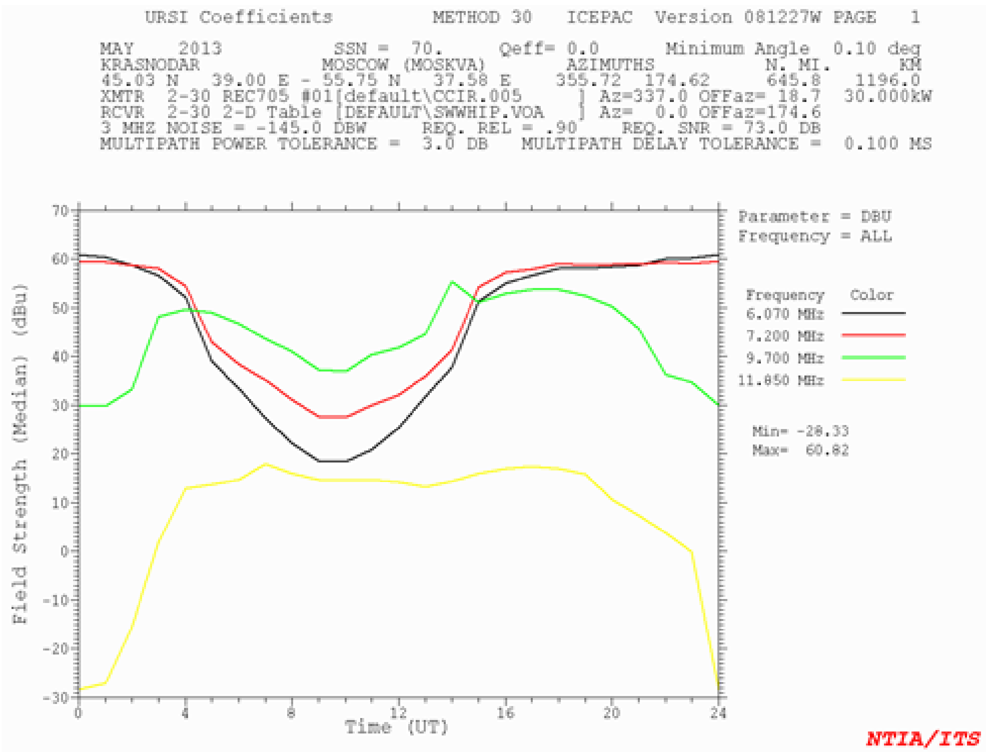
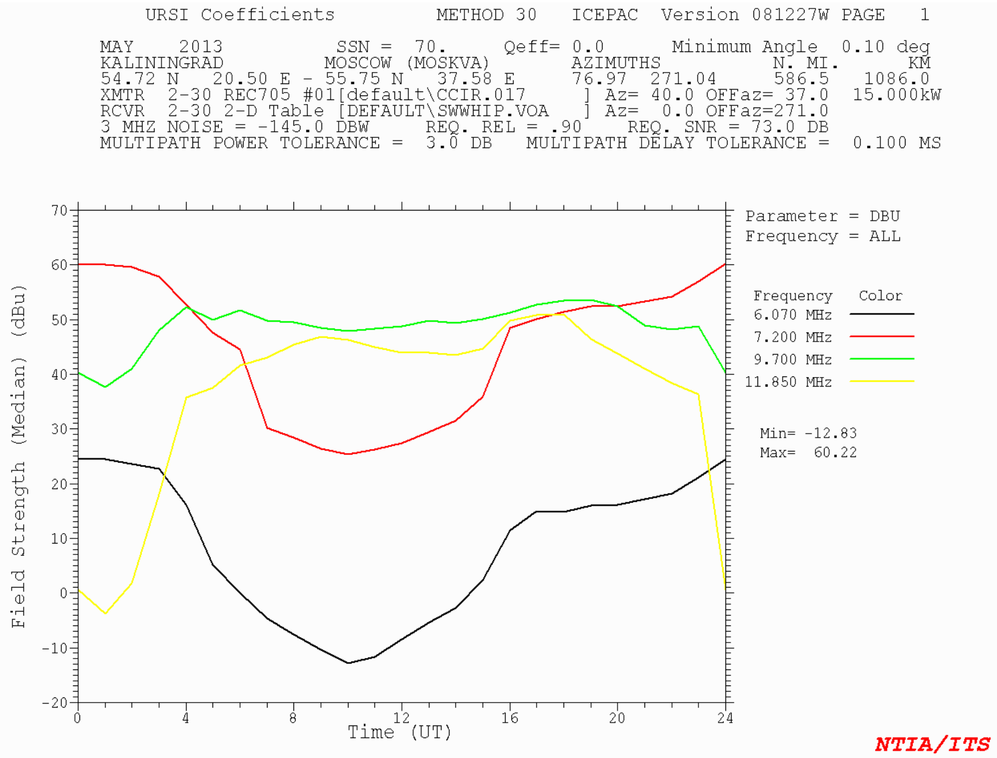


FIGURE 12

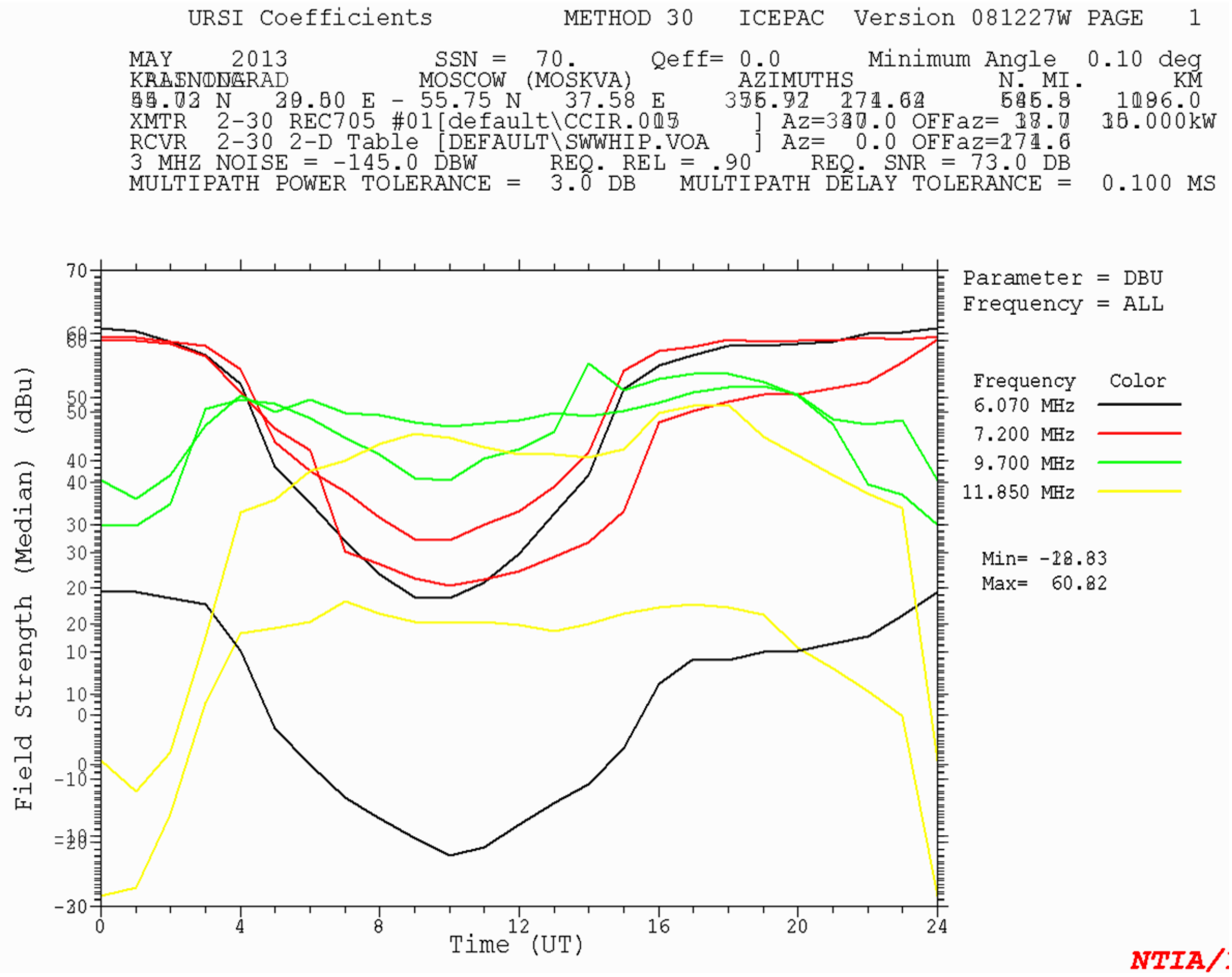
**Calculated field strength (within 24 hours) for the various frequencies in the measuring point in the Moscow region of Kaliningrad transmitter**




Overlaying these graphs against each other (see Fig. 13) makes it possible to determine, roughly equally (up to 10 dB) and sufficient for decoding, the values of field intensity for day time in the 9.7 MHz frequency range and for night time within the 7.2 MHz frequency range.

FIGURE 13

**Overlay plots of field (within 24 hours) for the various frequencies in the measuring point in the Moscow region of Krasnodar and Kaliningrad transmitters**




## 3 The composition and characteristics of transmitting equipment

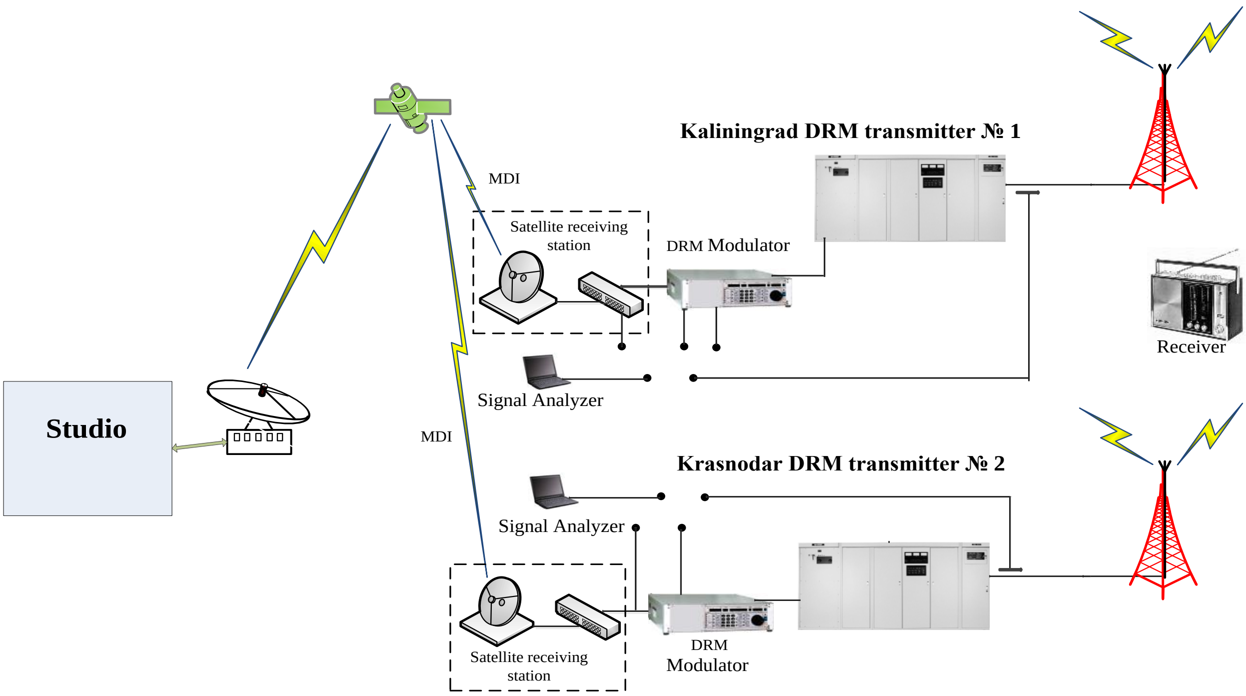
Figure 14 illustrates the organization of the work of the technical equipment to create experimental zone of synchronous DRM shortwave radio. The audio content coming from the studio is processed by the "Optimod" sound processor to improve the perception and is served on the DRM content server, which performs encoding of audio signals, adding textual and service information, and then transmits it in the MDI format to the channel–forming equipment of the network.

The signal is received by a satellite receiving station. From the satellite receivers MDI signals go to DRM modulators that form the work frequency DRM signal. To operate synchronously DRM modulators are frequency and time synchronized by two GPS receivers each (not shown on the diagram). The generated electromagnetic signal is amplified to the level required in transmitters and antenna–feeder routes arrive at the antenna. The transmitters contain a complete set of equipment to ensure the configuration, measurement and control of the output signal.

DRM modulators are connected to the Internet, through which it is possible to remote control their settings.

FIGURE 14

**Organization of work of the technical means to create a pilot zone of synchronous broadcasting DRM in the SW range**




## 4 Receiving equipment

Stationary collection point was equipped in Moscow region. The terrain is characterized by low levels of industrial noise. Interference from home appliances on weekdays in the planned period (month of May) is also virtually non–existent.

Calibrated antennas used to measure the field strength (e.g. FMA–11) are very large antenna factor (Ka = –36 dB) that does not permit to use their DRM to receive signals in the case of a relatively small field intensity. Therefore, broadband receiving antenna type "T2FD" was designed, constructed and installed to conduct tests of synchronous network. Antenna calculation was made on the basis of terrain characteristics to provide attaching it to existing constructions, and the antenna factor is close to zero dB.

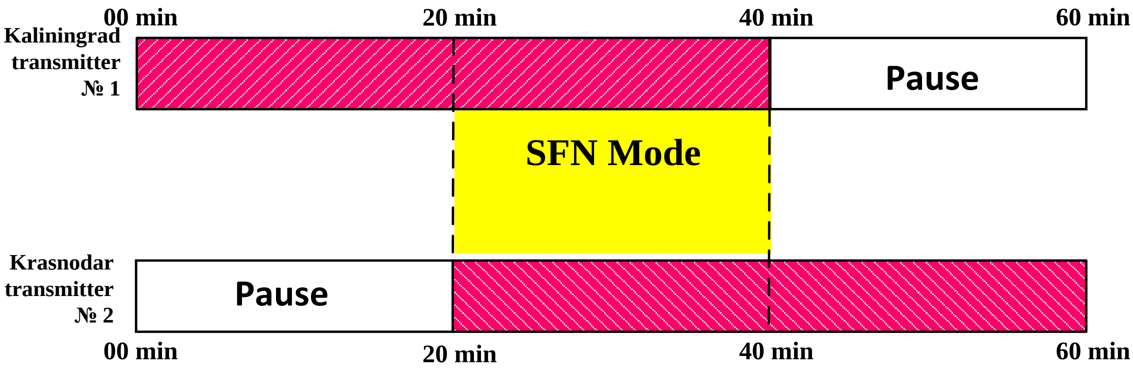
Moreover, a short whip antenna connected directly to a 50 Ohm–input of the measuring receiver was prepared. It was Ka ≈ –20 dB.

## 5 Testing

In previous experiments [3] the comparative measurements of synchronous network with separate constituent transmitters were carried out on different days. The radio propagation conditions could be very different due to changes in solar activity. In cases like that true measurements could only be obtained with a long set of statistics that are only possible with regular broadcasting. To avoid this effect tests were suggested to be conducted by the following algorithm of the work of transmitters as presented in Fig. 15.

FIGURE 15

**Mode of operation of transmitters**




As within one hour the conditions of radio propagation in first approximation do not change dramatically (with the exception of the dawn), the use of this mode of operation allows to determine the efficiency of the work of synchronous network. A breakdown of the time periods into smaller slots (less than 20 minutes) would take into account the "slow" feeding associated with the processes of change of absorption in the ionosphere.

To evaluate the performance of synchronous network with relatively weak signals (low field strength predicted) it was decided to hold 24-hour tests in each of the selected frequency ranges.

Tests ensured measurements and analysis of the field strength values as well as of parameters of the signal DRM transmitters (signal/noise ratio, the percentage of correctly decoded audio) in various combinations according to the mode of operation of transmitters (Fig. 15).

The measurements were taken in at stationary reception. In addition, home receiver in/out audio control was conducted as well as the measurement of signal/noise ratio.

The signal field strength measurement in the reception area was performed with the use of DT700 measuring receiver and one Fraunhofer calibrated receiving antenna. Start to finish of each hourly séance DT700 Fraunhofer receiver continuously produced a corresponding measuring record of DRM files in RSCI format, containing the information on the field, MER, percentage, correctly decoded audio units as well as the time delay between the signals of the transmitter.

## 6 Preliminary measurement of field strength essential noise and interference from other stations

To obtain correct results is important to ensure not only the desired field strength, but also quite low level of interference from other stations in the workplace and the neighbouring channels. To ensure this condition, field strength of essential noise and interference from other stations on all selected frequencies and neighbouring channels has been measured throughout the day. Measurements of the noise carried out at the same point where the subsequent measurements of useful signal. Max "clean" frequencies were used during the experiment. Noise level is continuously controlled.

### 6.1 7.4 MHz frequency range

Median values of the measured field strength for each of the transmitters individually and when working in the synchronous network, as well as the calculated median values in the range 7.4 MHz are shown graphically in Fig. 16.

Minimum requirements for the sensitivity of the receiver in the range 6.2-27 MHz in accordance with [4] is 28 dBμV/m. It is clear that in case the signal field strength drops lower then receiver sensitivity, reception becomes impossible.

In the case of transmitter № 1 (Kaliningrad) there are 7 time intervals during which the minimum field strength fell below 28 dBμV/m. When transmitter № 2 (Krasnodar) works there are 5 time intervals, and only 1 synchronous network.

The most illustrative case of the increase of the minimum field strength used in the synchronous network is an example of the "6 hours" interval, when the minimum field strength of the transmitter № 1 amounted to 39.35 dbμV/m, whereas that of transmitter № 2 – 41.4 dBμV/m, and of the synchronous network – 51.63 dBμV/m.

### 6.2 9.7 MHz frequency range

Median values of the measured field strength for each of the transmitters individually and when working in the SFN, as well as the calculated median values in the range 9.7 MHz are shown graphically in Fig. 17. Transmitter № 1 has 6 hour intervals during which the minimum field strength falls below 28 dBμV/m, whereas transmitter № 2 has 3 such time intervals, and the synchronous network has only 1.

## 7 Percentage of decoded audio

Calculated for each time interval measurement value is correctly decoded audio units, expressed as a percentage, for each of the transmitters individually and when working in the synchronous network for 7.4 MHz frequency range and 9.7 MHz are shown graphically in Figs 16 and 17.
The graphs vividly show that when using traditional "broadcast day" and "night" frequency (for example, 7.4 MHz in the frequency range from 00 MSK to 09 MSK and 9.7 MHz range 09 MSK on 23 MSK) it is possible to provide broadcast quality with high reliability (i.e. 98% audio decoding) within 24 hours.

## 8 Modulation error ratio (MER)

As it can be seen from the diagram, Fig. 16, 7.4 MHz in the frequency range of the (24.67 dB) is higher than that of individual transmitters (21.69 dB and 23.83 dB, respectively). The minimum value for this parameter is well above average per day: 10.88 dB against 6.55 dB and 8.00 dB, respectively.

As it can be seen from the diagram, Fig. 17, in 9.7 MHz frequency range MER median day average of a synchronous network (25.32 dB) is higher than that of individual transmitters (22.61 dB and 24.31 dB, respectively). The minimum value for this parameter is well above average per day: 13.14 dB and 10.35 dB against 11.45 dB, respectively.

As the minimum field strength, the analysis above provides only a qualitative notion that synchronous network provides power gains compared with the work of the individual transmitters. With the increase of the minimum value of the MER for synchronous network the number of decoded audio samples exceeded the criterion considered comfortable for listening (98% of decoded audio units) with the work of individual transmitters.

FIGURE 16

**The reception within the range 7.4 MHz**

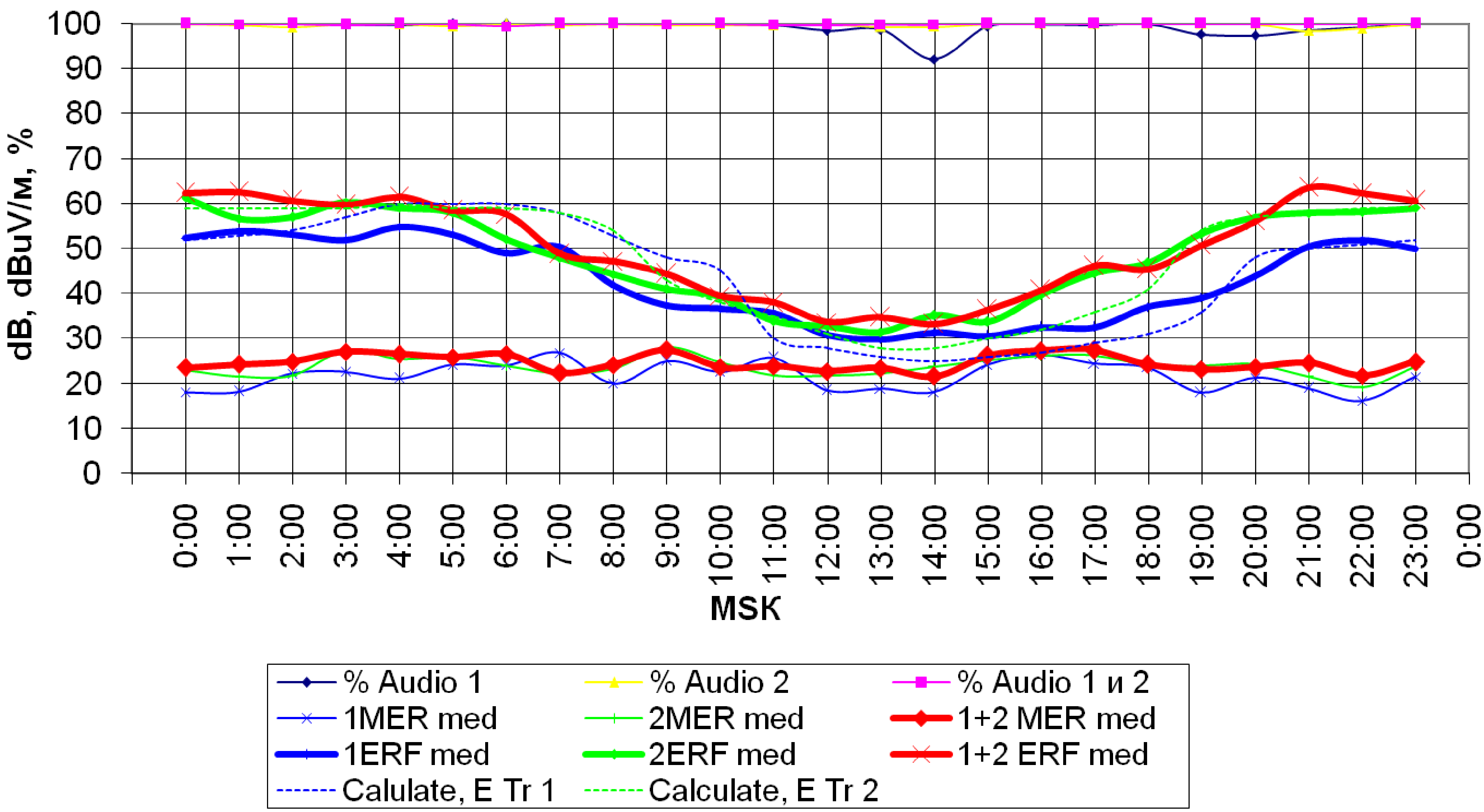
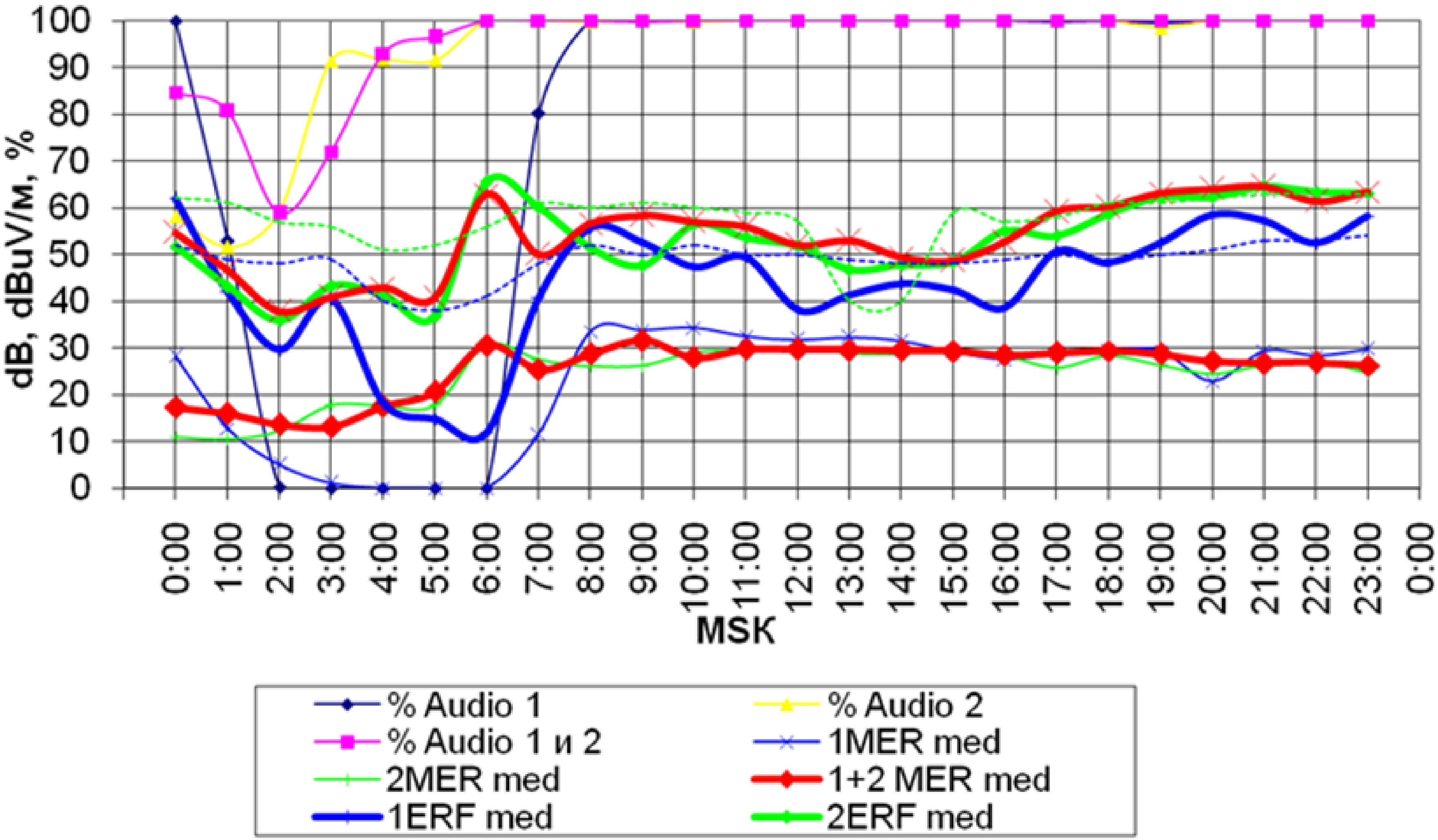


FIGURE 17

**The reception within the range 9.7 MHz**



# 9 Network gain evaluation

In shortwave, studied in the present work, the difference in the projected median daily values of field strength in ionospheric channel distribution can be more than 30 dB (see Figs 11 and 12). The measured minimum field strength values were 40 dB less than the maximum median values (see Figs 16 and 17). In this situation, in order to ensure decoding service channels (and receive MER data throughout the measurement period) it is sufficient to provide a sufficiently large high field strength in a place with low levels of essential interference, as well as the use of DRM with a fairly high noise immunity.

For this reason, DRM noise immunity measurement mode of 10 kHz, 16QAM, *rall* = 0.62 (protection level N 1) was used. To decode this mode in different types of ionospheric channels MER to 13 dB to 21 dB is required, with a data transfer rate of 14.56 kbit/s, which allows to use SBR and transmit audio content with high quality [3]. Minimum field strength used for this mode noise immunity is, in accordance with [3], 22 – 25 dBµV/m.

However, it is clear that with the growth of the field strength due to radio propagation conditions change, there will be close to 100% audio decoding, and MER at the reception point will be limited to the value of the transmitter output (32 ...34 dB) which it cannot exceed/

Net gain (in dB) can be identified by comparing the thresholds in each time interval for each of the transmitters individually and as part of a synchronous network.

Calculated for each measurement time interval values allowed MER expressed in decibels, for each of the transmitters individually and when working in the synchronous network for 7.4 MHz frequency range and 9.7 MHz are represented graphically in Figs 18 and 19.

FIGURE 18

**Dependence value MER 98% decoding audio units to the time of day at the range 7.4 MHz**

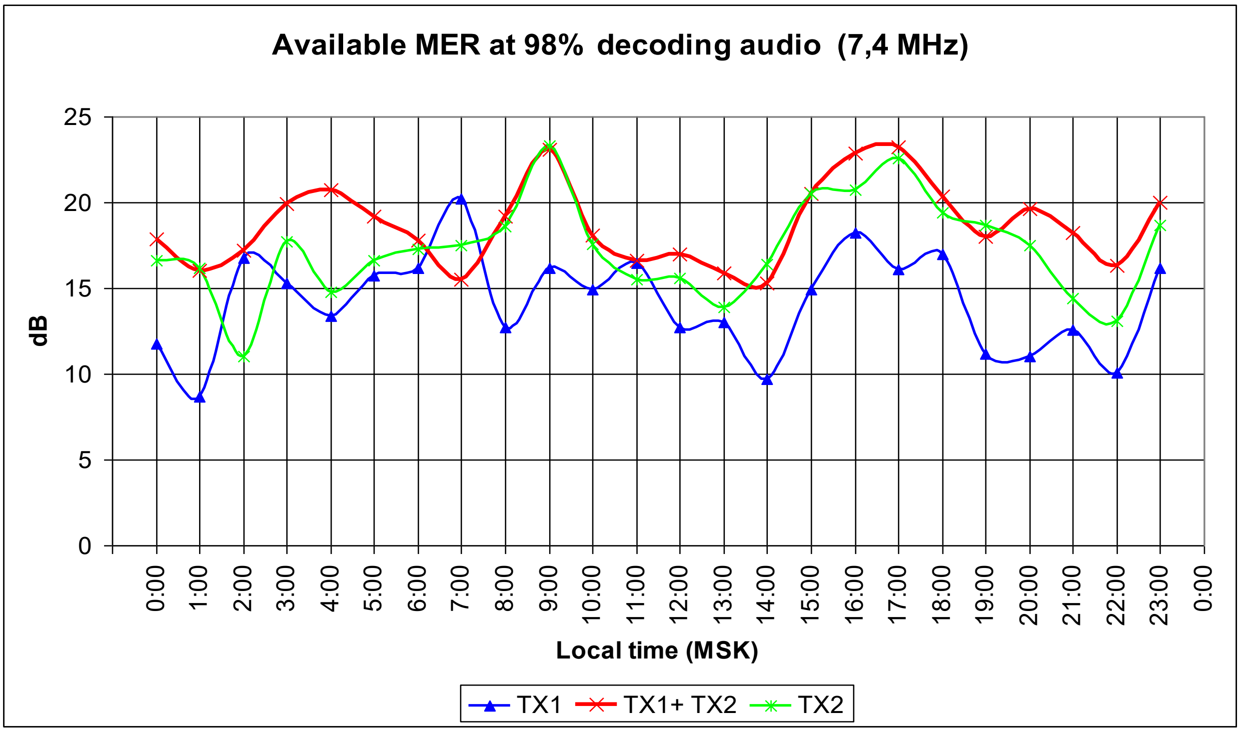
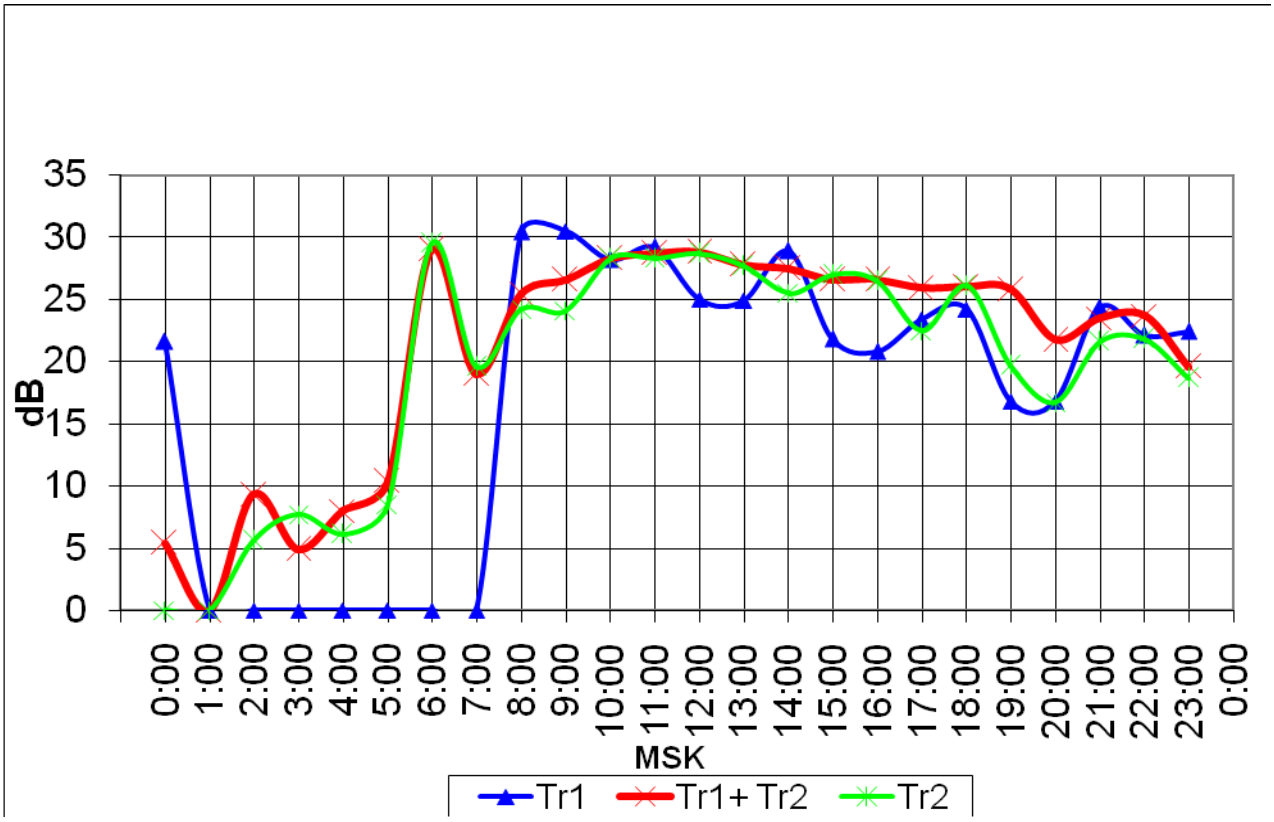


FIGURE 19

**Dependence value MER 98% decoding audio units to the time of day at the range 9.7 MHz**




As illustrative cases, examples include:

| Time MSK/frequency, (MHz) | Transmitter 1, Aet. SNR, dB/dekod. Audio (%) | Transmitter 2. Aet. SNR, dB/dekod. Audio (%) | The transmitters 1 and 2, Aet. SNR, dB/dekod. Audio (%) | Win SFN, (dB) |
|---|---|---|---|---|
| 4:00 / 7,4 | 13,4 / 99,83 | 14,8 / 99,94 | 20,7 / 100 | 5,9 |
| 19:00 /9,7 | 16,8 / 99,48 | 19,7 / 98,46 | 25,8 /100 | 6,1 |

The reception was performed under artificially degraded conditions (at 1 metre long whip antenna that is connected directly to a 50 Ohm–input of the measuring receiver, which corresponds to some domestic sinks with not very good alignment of the antenna) and revealed much greater potential for the network gain.

| Time MSK/frequency, (MHz) | Transmitter 1, Aet. SNR, dB/dekod. Audio (%) | Transmitter 2. Aet. SNR, dB/dekod. Audio (%) | The transmitters 1 and 2, Aet. SNR, dB/dekod. Audio (%) | Win SFN, (dB) |
|---|---|---|---|---|
| 19:00 /9,7 | 15,2 / 99,95 | 14,1 / 99,22 | 26,6 /100 | 11,4 |

As you can see from the time chart in Figs 20 and 21, with synchronous operating mode (an average of 20 minutes a day) field strength and MER have fewer "deep" failures, than with each of the individual transmitters working – in the first and the last 20–minute intervals. The calculated permissible MER thresholds allow receiving a quantitative value network win, which in the conducted experiments reached the values up to 6 dB at a wire antenna and up to 11 dB at a whip antenna.

FIGURE 20

**Time diagrams MER field strength and properly decoded audio for hour interval "4 hour, 7.4 MHz". Synchronous mode in the middle part of the graph is shown between the yellow markers**

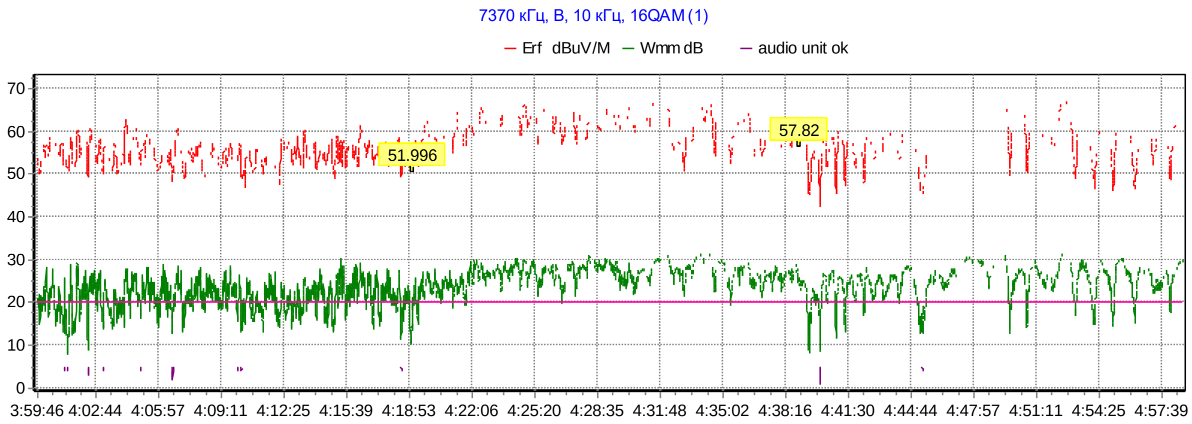
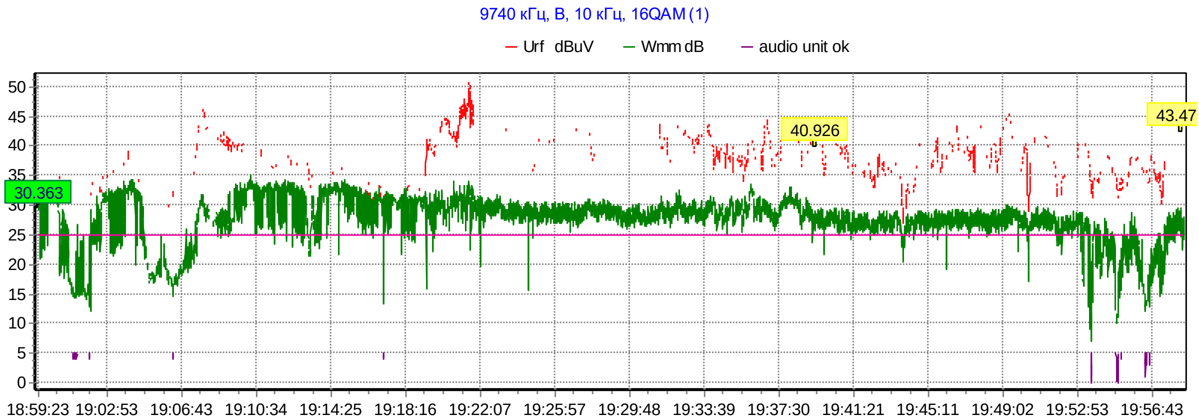



FIGURE 21

**Time diagrams MER field strength and properly decoded audio for hour interval "7 hour, 9.7 MHz whip antenna". SFN mode is shown in the middle part of the graphics**




## LIST OF REFERENCES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[2] DRM Introduction and Implementation Guide. 08.2012. www.drm.org.

[3] Report ITU–R BS.2144 – Planning parameters and coverage for Digital Radio Mondiale (DRM) broadcasting at frequencies below 30 MHz.

[4] Digital Radio Mondiale (DRM); Minimum Receiver Requirements. Version 1.0. http://www.drm.org/wp–content/uploads/2012/10/DRM_Minimum_Requirements1.


*[Editorial note: Added new Attachment 1.3 here derived from Part 1 of Doc. 6A/299).]*

ATTACHMENT 1.3
TO ANNEX 1

# DRM30 trial project covering the greater Pretoria area and the northern parts of Johannesburg

## 1 Introduction

This report contains the measurement results and the findings on the Radio Pulpit DRM30 Trial. Measurements were conducted successfully on the 10 kW DRM30 transmitter.

Herewith follows a brief list of events in chronological order as it relates to the DRM trial:

– Radio Pulpit was granted the DRM trial licence mid-April 2014;
– The DRM transmitter site which included the Broadcom was prepared and operational May 2014;
– First DRM broadcast in South Africa went on-air the 1st of June 2014;
– DRM technical configuration set-up was completed at the end of August 2014;
– DRM broadcast with normal program content started on the 1st of September 2014;
– The delivery of the DRM test equipment was delayed and arrived during January 2015;
– Radio Pulpit requested a 6 months extension of the trial licence early in February 2015;
– Antenna and DRM performance tests using the Broadcom low-profile antenna were completed at the end of March 2015, herein after referred to as phase 1 and 2 measurement test exercises;
– Radio Pulpit was granted an extension for the DRM trial up to the 16th of October 2015;
– Antenna and DRM performance tests using the KinStar low-profile antenna were completed at the beginning of October 2015, herein after referred to as the phase 3 and 4 measurement test exercises;

This report contains the results and findings for tests performed during all measurement exercise test phases (1 to 4). The measurement exercises were conducted by using the following main transmitter station components:

– DRM30 transmitter;
– Broadcom low-profile antenna;
– KinStar low-profile antenna.

## 2 Background information

DRM30 is a broadcasting system designed as an improvement of current analogue Amplitude Modulated (AM) radio broadcast systems.

The DRM30 broadcasting system was designed to be a high quality digital replacement or co-existing system for analogue radio broadcast systems in the AM frequency band (long wave, medium wave and short wave). In terms of spectrum allocations, channel plan and impact on existing listeners, the technology requires minimal additional regulatory intervention as it was designed to operate in the same frequency bands and channel arrangements as the existing analogue services. The impact on existing AM listeners will therefore be minimal as the technology was also designed to operate in simulcast mode which allows the transmission of both digital and analogue services from the same transmitter on the same frequency channel. Unlike analogue radio services, digital radio broadcasting technologies allow more efficient utilization of the frequency bands, e.g. DRM30, DRM+ and DAB+. Additional services and value added services can also be provided without the requirement of additional frequency spectrum due to the digital based design of the system.

In this regard the technology should prove to be efficient, effective in spectrum usage with the capability to incorporate additional services providing an innovative platform for both the listeners and broadcasters. Compatibility of the DRM30 digital service with existing analogue services should also assist interested broadcasters to phase-in the conversion from analogue to digital broadcasting. This would also allow the spread of the required investment over a period of time with limited impact on existing services and budget constraints.

Radio Pulpit obtained a temporary DRM broadcasting licence from the Independent Communications Authority of South Africa (ICASA) to undertake a DRM30 trial project to broadcast on the DRM30 standard covering the greater Pretoria area and the northern parts of Johannesburg. The Radio Pulpit DRM30 trial was conducted in collaboration between Radio Pulpit, Sentech and Broadcom International cc.

The trial consisted of four measurement phases:

– Test Phase 1 - Evaluation of Broadcom Antenna;

– Test Phase 2 - DRM30 Signal Coverage Evaluation - Broadcom Antenna;

– Test Phase 3 - Evaluation of KinStar Antenna;

– Test Phase 4 - DRM30 Signal Coverage Evaluation - KinStar Antenna;

## 3 Objectives

The main objectives of the DRM30 measurement trial are listed as follow:

Confirm the potential benefits of the DRM30 technology as a radio broadcast platform;

– Evaluation of actual coverage versus predicted coverage (for both Ground and Sky-wave propagation modes);

– Evaluation of two different low-profile AM antenna systems (herein after referred to as the Broadcom & KinStar antennas respectively);

– Obtain sufficient measurement data for analysis to assist in reaching a conclusion on the overall performance of the technology;

– Determine if, how and where the technology could be applied to benefit broadcasters;

– Evaluation of available commercial radio receivers in both fixed and mobile conditions.

## 4 Potential benefits of the DRM30 technology

Potential benefits of the DRM30 technology in the MW broadcast band are as follow:

– Exploit some unique signal propagation qualities which are only available in the MW frequency band, more specific wide area coverage and sky-wave propagation;

– Allows select-ability between various capacity and robustness modes for optimum performance, depending on the broadcaster’s requirements with regard to area coverage and audio quality;

– Enhanced audio compression which improves efficient utilization of the digital channel;

- Good audio quality;
- Ability to enhance listener's experience;
- Provide additional features, such as Electronic Program Guide, Journaline, News Feeds and Slideshow (pictures);
- Emergency Warning Feature (EWF);
- Single-Frequency-Network (SFN) operation which allows more efficient use of limited spectrum;
- Hand-over capability between different radio platforms or networks (between DRM, DAB+ and FM);
- Capability to operate in current existing analogue Medium Wave (MW) frequency bands;
- Capability to operate in simulcast mode (i.e. broadcasting analogue and digital simultaneously).

# 5 Technical information on DRM30 system

## 5.1 Transmitter

The transmitter used to broadcast the MW signal was the Ampegon M2W 25 kW DRM transmitter, shown in Figure 1, which was configured according to the basic technical specifications listed in Table 1. Antenna input current was measured and the transmitter output power was adjusted to 10kW at the input point to the antenna.

TABLE 1

**Transmitter Specifications**

| No | Description | Value |
|---|---|---|
| 1 | Transmitter Power | 10 kW (mean) DRM30 |
| 2 | Transmit Frequency | 1440 kHz |
| 3 | Frequency Band | MF |
| 4 | Modulation | DRM30 - Mode A |
| 5 | Bandwidth | 9kHz |

FIGURE 1

**Ampegon M2W 25kW DRM Transmitter**


The Broadcom antenna shown in Figure 2 is a short (24 meters) folded monopole antenna designed by Broadcom which consisted of a capacitive top loading and a diamond-shaped feed skirt to increase the frequency bandwidth capability required for DRM30 operation.

The antenna was tuned to resonance and impedance matched to 50 Ohms before connecting it directly to the RF feeder without any additional tuning elements.

The basic antenna specifications are listed in Table 2:

TABLE 2

**Broadcom Antenna Specifications**

| No | Description | Value |
|---|---|---|
| 1 | Manufacturer | Broadcom |
| 2 | Installer | Broadcom |
| 3 | Type | Mast Radiator |
| 4 | Input Impedance | 48.8Ω - j0.1 |
| 5 | VSWR | 1.08:1 at ±5 kHz |
| 6 | VSWR | 1.17:1 at ±10 kHz |
| 7 | Height | 24m |
| 8 | Beam Width | 360° |
| 9 | Polarisation | Vertical |

Measured Broadcom Antenna Radio Frequency (RF) response is graphically presented in Figure 3.

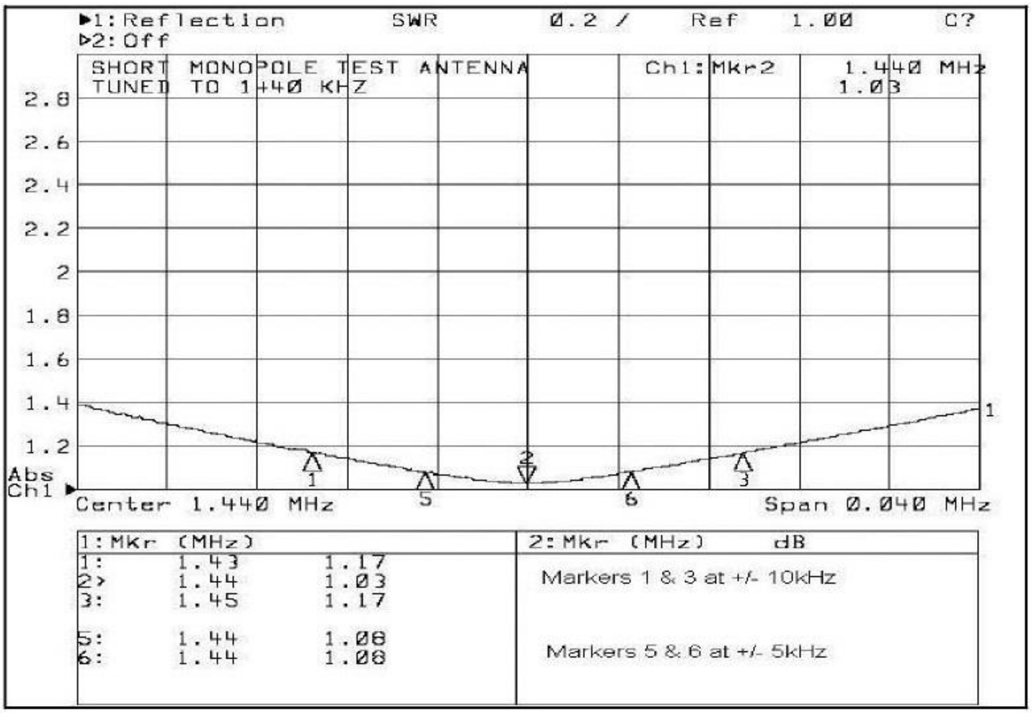
Broadcom's low-profile MF antenna system was used for antenna directivity measurements as well as signal coverage measurements (phase 1 and 2).

FIGURE 2

**Broadcom Short Vertical Antenna**

FIGURE 3

**Measured Broadcom Antenna RF Response**



## 5.3 KinStar antenna system

The KinStar antenna shown in Figure 4 is a new reduced height antenna designed by Star-H Corporation and manufactured by Kintronic Laboratories and consists of four horizontal and vertical radiating wires. The lengths and arrangements of the wires were designed by computer optimization methods to provide the best compromise between reduced antenna height, antenna gain and frequency bandwidth. Total height of the KinStar antenna used in this trial was 20 meters.

An ATU (Antenna Tuning Unit) also formed part of the antenna system to match the antenna’s input impedance to the transmitter’s output impedance.

Basic antenna specifications of the KinStar low-profile MF antenna system are listed in Table 3.

TABLE 3

**KinStar Antenna Specifications**

| No | Description | Value |
|---|---|---|
| 1 | Manufacturer | Kintronic Labs |
| 2 | Installer | CTB |
| 3 | Type | Mast Radiator |
| 4 | Input Impedance | 50Ω + J0 |
| 5 | VSWR | 1.03:1 at ±5 kHz |
| 6 | VSWR | 1.08:1 at ±10 kHz |
| 7 | Height | 20m |
| 8 | Beam Width | 360° |
| 9 | Polarisation | Vertical |

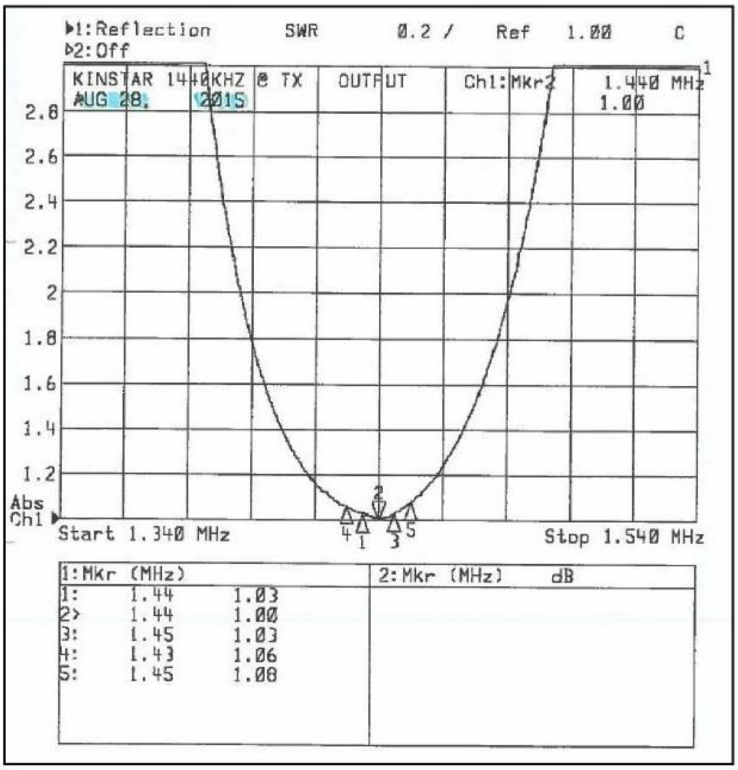
FIGURE 4

**KinStar low profile antenna**

The measured Kinstar antenna Radio Frequency (RF) Response is graphically presented in Figure 5. Antenna directivity measurements as well as signal coverage measurements were conducted on the KinStar low-profile MF antenna system (phase 3 and 4)

FIGURE 5

**Measured KinStar Antenna RF Response**




# 6 Measurements

## 6.1 Initiation of measurement exercise

Radio Pulpit and Broadcom International established a DRM30 trial broadcast platform and Sentech agreed to participate in the DRM30 trial by providing an alternative antenna (KinStar), as well as support in terms of conducting measurement exercises with the main objective to determine the functional capacity and capability of the DRM30 technology.

An alternative antenna was purchased from Kintronic Laboratories and installed by CTB (Communications Technology Broadcasting) in the later stage of the DRM30 trial. This antenna was constructed on the exact same location as the previous antenna (previous Broadcom antenna was dismantled).

Measurements exercises were planned in different phases (phase 1 to 4) and scheduled accordingly.

**Phase 1:** measurement exercise focused on the Broadcom antenna's performance which was scheduled over a period of two days and conducted from the 17th to the 18th of September 2014. A preliminary measurement report for phase 1 was completed on the 30th of September 2014 of which the findings are also included in this report.

**Phase 2:** measurement exercise focused on DRM signal coverage measurement of the signal broadcasted using the Broadcom antenna was scheduled over a period of eight days and conducted from the 16th to the 26th of March 2015. Measurement data was analysed and the results and findings were also compiled in this report.

**Phase 3:** measurement exercise focused on the KinStar antenna performance which was scheduled over a period of three days and conducted from the 15th to the 17th of September 2015. Measurement data was analysed and the results and findings also compiled in this report.

**Phase 4:** measurement exercise focused on DRM signal coverage measurement of the signal broadcasted using the KinStar antenna was scheduled over a period of eight days, conducted from the 22th of September 2015 to the 2nd of October 2015. Measurement data was analysed and the results and findings were also compiled in this report.

Additional measurements were also conducted on the KinStar antenna which focused on the analogue AM signal coverage which was also scheduled over a period of two days and conducted from the 5th to the 6th of October 2015. Analysis and findings are also compiled in this report.

### 6.2 Measurement tools

Various measurement tools were used to conduct the required measurements and are listed below:

– input current to the antenna system was measured with a Delta Electronics Peak RF Meter and used to calculate the input power to the antenna system;

– antenna input impedance was measured by using a Hewlett-Packard (HP) RF Network Analyzer (8712B);

– static measurements were conducted at fixed pre-determined locations using the Photomac (PI 4100), Fraunhofer (DT700) and RF Mondiale DRM Monitoring Receiver (RF-SE12) measurement tools;

– drive-by measurements were conducted using a RF Mondiale DRM Monitoring Receiver (RF-SE 12);

– Antenna Tuning Unit (ATU) measurements were conducted using HP Network Analyzer (8712B) and HP Communication Test Set Hewlett Packard measurement tools (VSWR measurements).

Details of measurement tools used are shown in Table 4:

TABLE 4

**Measurement Tools**

| No | Description | Manufacturer / Supplier | Model / Code |
|---|---|---|---|
| 1 | Peak RF current meter | Delta Electronics | TCT-1 |
| 2 | RF Network Analyzer | Hewlett-Packard | 8712B |
| 3 | Active Rod Antenna | Rohde & Schwarz | R&S®HE010E |
| 4 | Bias Unit | Rohde & Schwarz | R&S®IN600 |
| 5 | DRM Monitoring Receiver RF-SE | RFmondial | Model RF-SE12 |
| 6 | DRM30 Domestic Receiver | NewStar | DR-111 |
| 7 | DRM30 Domestic Receiver | Himalaya | DRM2009 |
| 8 | DRM30 Domestic Receiver | Morphy Richards | 27024 |
| 9 | DRM30 Domestic Receiver | Uniwave | Di-Wave 100 |
| 10 | Communication Test Set | Hewlett-Packard | 8920A |

## 6.3 Measurement method

Measurements were conducted on planned locations and routes which consisted of both static measurements as well as Drive-By measurements. Static measurement results were mainly used to determine antenna performance and Drive-By measurement results used to conduct signal coverage verification. Static measurements on the routes were identified based on incident findings (e.g. Audio loss, audio recovery etc.)

Only the static point measurement method was used to conduct basic antenna performance measurements. Measurements were conducted at a height of approximately 1.5 meters above ground level and consisted of one measurement per static point. Measurements were conducted at distances of 0.5km, 1km, 2km and 5km from the transmitter station in 8 main predetermined radial directions (0º, 45º, 90º, 135º, 180º, 225º, 270º and 315º). The transmitter was configured to provide an analogue pilot signal during the antenna measurement exercises.

Drive-By measurements were conducted at a height of two meters at a measurement sampling rate of four measurements per second at a maximum speed of 90 km/h. These measurements were conducted on eight pre-planned radial routes over a period of eight days. Measurements were conducted by driving outwards on each radial with the MSC (Main Service Channel) configured on a lower modulation setting (16QAM) up to the point where complete audio failure occurred. Once audio failure detection was confirmed, the same route was measured in the opposite direction back to the transmitter, with the MSC configured to a higher modulation setting (64QAM). This measurement sequence was repeated for all eight planned radial routes. The transmitter was configured to transmit a DRM30 signal during the coverage measurement exercises.

Static measurements were conducted at fixed locations on the planned routes by using the Drive-By measurement tool. These static measurement points were either located at pre-identified measurement test point locations (e.g. major towns), or incident point locations (where audio failure or recovery occurred) identified during the Drive-By measurement exercise. Static measurements were conducted at a height of approximately two meters above ground level at predetermined and incident locations.

Limited analogue AM measurements were also conducted for comparison purposes between analogue (AM) and digital (DRM30). Drive-By and static measurements for AM and DRM30 comparison purposes were conducted only on the northern and southern radial routes.

Services were monitored and measured on all the planned routes. Whenever measurement incidents (e.g. loss of audio, decode-ability, recovery of audio etc.) were experienced the coordinates, measurement parameters and incident details were logged and noted.

## 6.4 Measurement data

Drive-By measurement data measured by the DRM Monitoring Receiver (RF-SE12) was logged, downloaded and converted to the appropriate format for coverage and statistical analysis purposes.

## 6.5 Measured parameters

DRM30 parameters measured are listed in recommendation ETSI ES 201 980. Receiver Profile A was chosen, which include parameters like time, GPS coordinates, RF level etc.

## 6.6 DRM30 configuration parameters

Configuration parameters used for the DRM30 16QAM, 64QAM and Analogue Modulation (AM) configuration settings are provided in Tables 5, 6 and 7 below:

TABLE 5

**DRM30 16QAM Parameter Configuration**

| | |
|---|---|
| Robustness mode | DRM Mode A, Long interleave |
| RF Spectrum occupancy | 9 kHz |
| FAC Mode | 4 QAM |
| SDC Mode | 4 QAM |
| MSC Mode | 16 QAM |
| DRM Channel | 12400 bps; |
| MSC Protection | EEP [0.5] |
| Audio coding | AAC (mono), Sampling Rate, 24kbps |
| Data services | Journaline enabled, PRBS enabled |

TABLE 6

**DRM30 64QAM Parameter Configuration**

| | |
|---|---|
| Robustness mode | DRM Mode A, Long interleave |
| RF Spectrum occupancy | 9 kHz |
| FAC Mode | 4 QAM |
| SDC Mode | 4 QAM |
| MSC Mode | 64 QAM |
| DRM Channel | 18000 bps |
| MSC Protection | EEP [0.5] |
| Audio coding | AAC (mono), Sampling rate 24kbps |
| Data services | Journaline enabled, PRBS enabled |
| Robustness mode | DRM Mode A, Long interleave |
| RF Spectrum occupancy | 9 kHz |

TABLE 7

**AM Parameter Configuration**

| | |
|---|---|
| Output power | 10 kW |
| Modulation | Amplitude Modulation (double sidebands) |
| Bandwidth | 9 kHz |

## 6.7 Antenna measurement test points

Static measurement test points were identified and planned for the antenna measurement exercise. The number of test points identified consisted of 32 measurement test points around the transmitter station which were located in eight different radial directions (0º, 45º, 90º, 135º, 180º, 225º, 270º and 315º), at four different distances (0.5 km, 1 km, 2 km and 5 km) from the antenna.

Test points are indicated on Figures 6 to 14. The details of each test point are tabled in Table 16 in Appendix A

FIGURE 6

**Test points (TP01 to TP08) in 8 radial directions located at a distance of 1km from the transmitter site. (ATDI ICS Telecom map)**

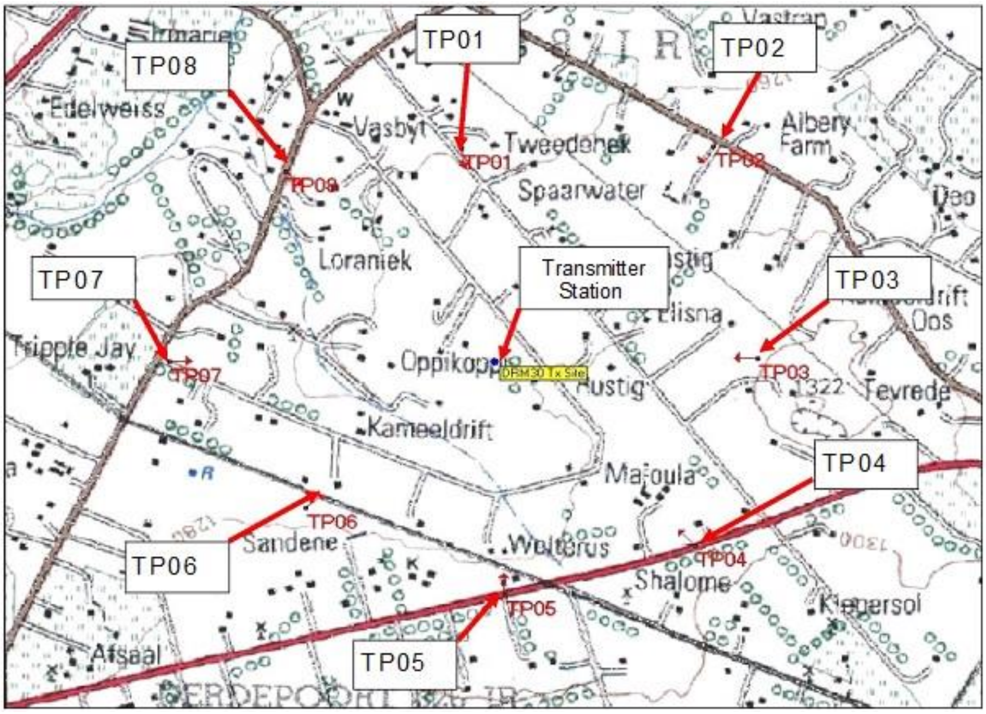



FIGURE 7

**Test points (TP01 to TP08) in 8 radial directions located at a distance of 1km from the transmitter site. (Google Earth Map)**

FIGURE 8

**Test points (TP09 to TP16) in 8 radial directions located at a distance of 5km from the transmitter site. (ATDI ICS Telecom map)**

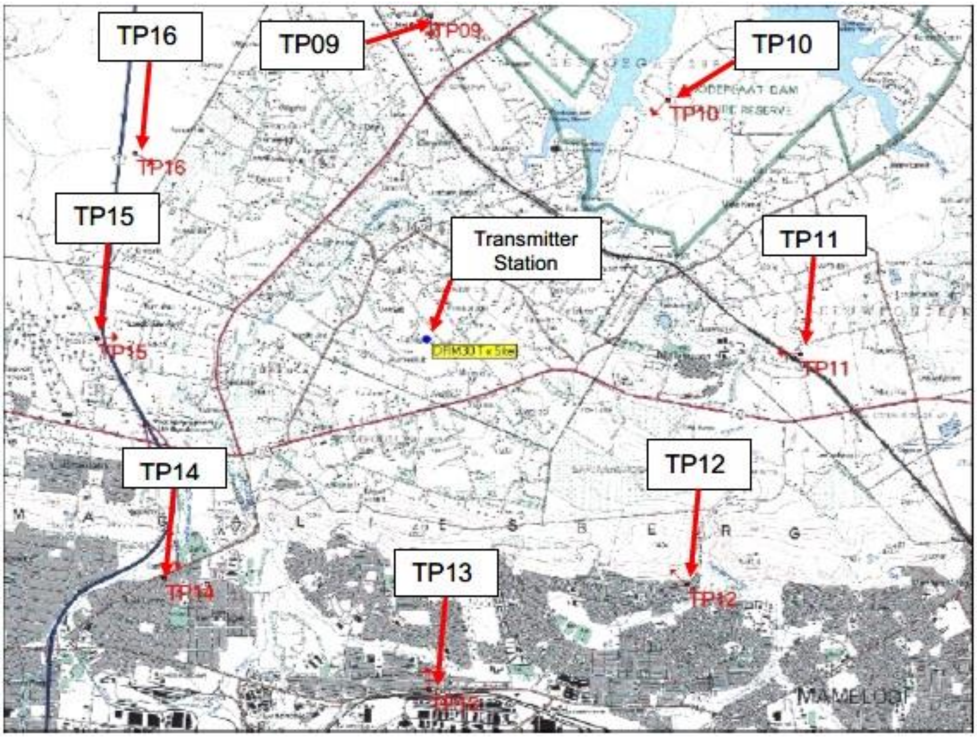



FIGURE 9

**Test points (TP09 to TP16) in 8 radial directions located at a distance of 5km from the transmitter site. (Google Earth Map)**

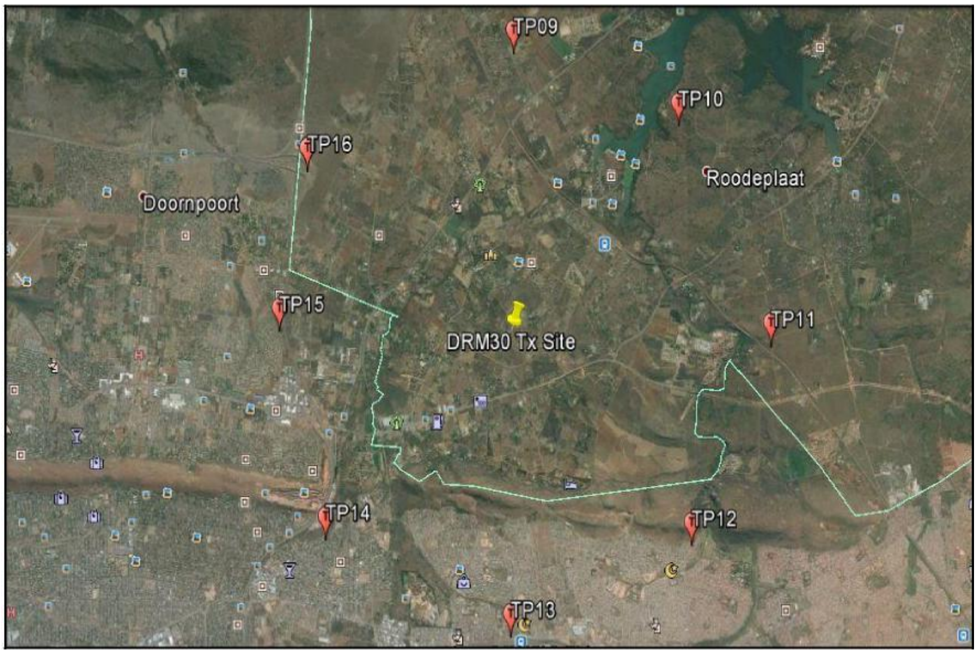


FIGURE 10

**Test points (TP17 to TP24) in 8 radial directions located at a distance of 2km from the transmitter site. (ATDI ICS Telecom map)**

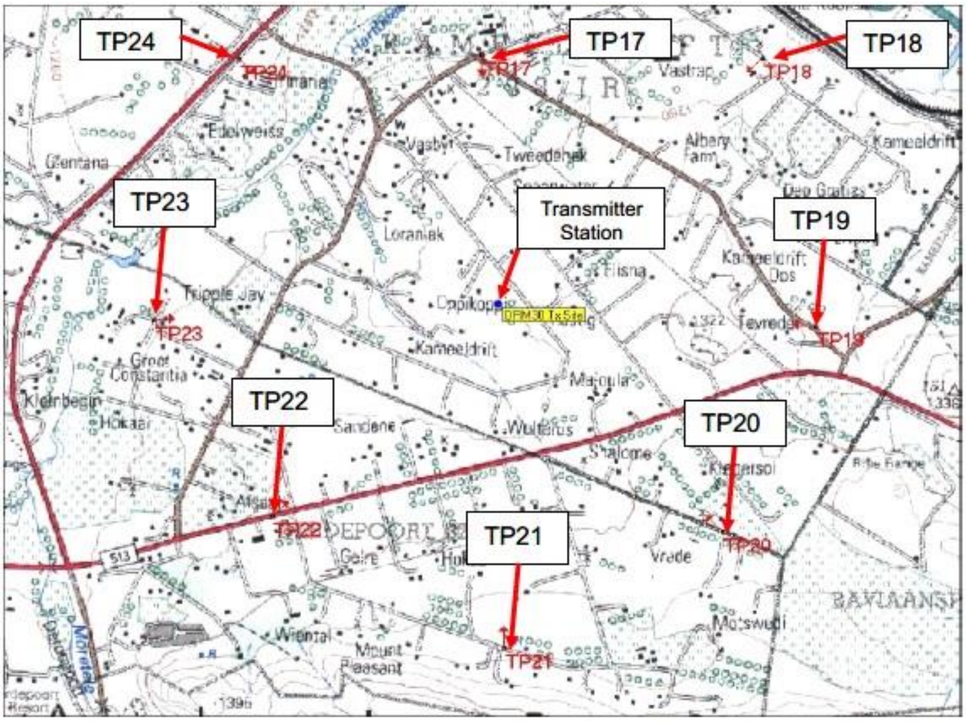



FIGURE 11

**Test points (TP17 to TP24) in 8 radial directions located at a distance of 2km from the transmitter site. (Google Earth Map)**

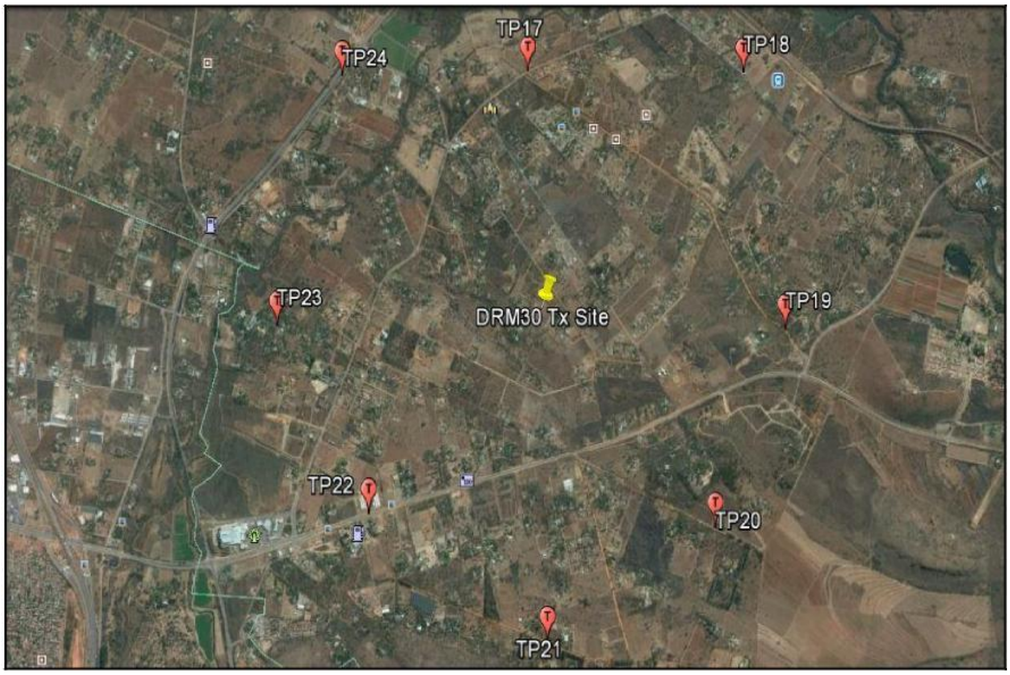


FIGURE 12

**Test points (TP25 to TP32) in 8 radial directions located at a distance of 0.5km from the transmitter site. (ATDI ICS Telecom map)**

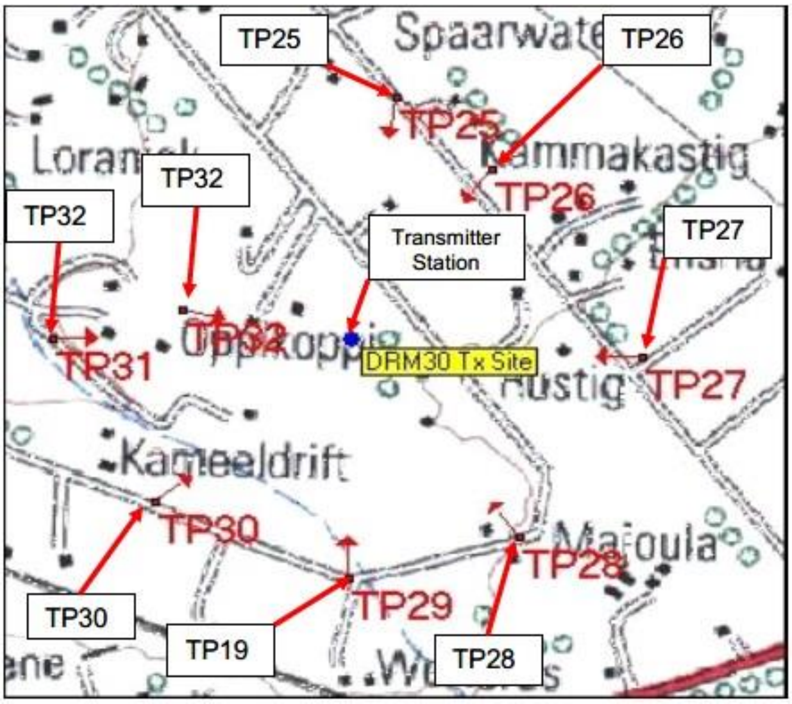
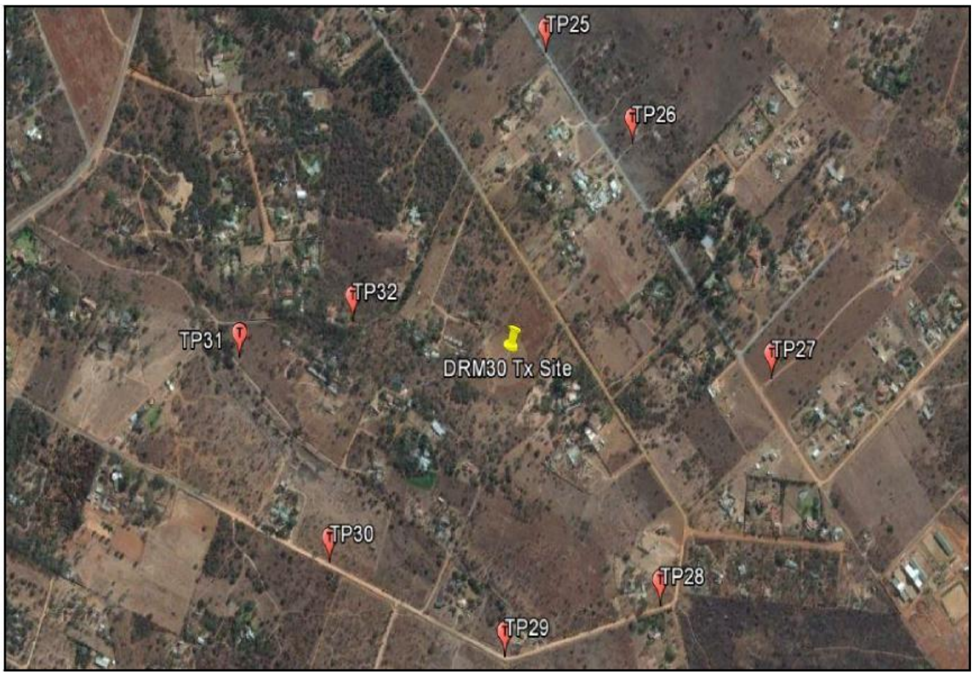



FIGURE 13

**Test points (TP25 to TP32) in 8 radial directions located at a distance of 0.5km from the transmitter site. (Google Earth Map)**



## 6.8 Drive-by measurement routes

Eight Drive-By measurement routes were planned for the coverage measurement exercise inside and outside the predicted coverage area indicated in Figure 14. The main objective for selecting these routes was to determine the maximum area covered and also to measure and monitor the signal quality within the coverage area. The four main radial routes were measured first (north, east, south and west), followed by the remaining four routes (north-east, south-east, south-west and north-west). Details on the various measurement routes are shown in Table 8 below.

FIGURE 14

**Drive-by measurement routes in eight radial directions**

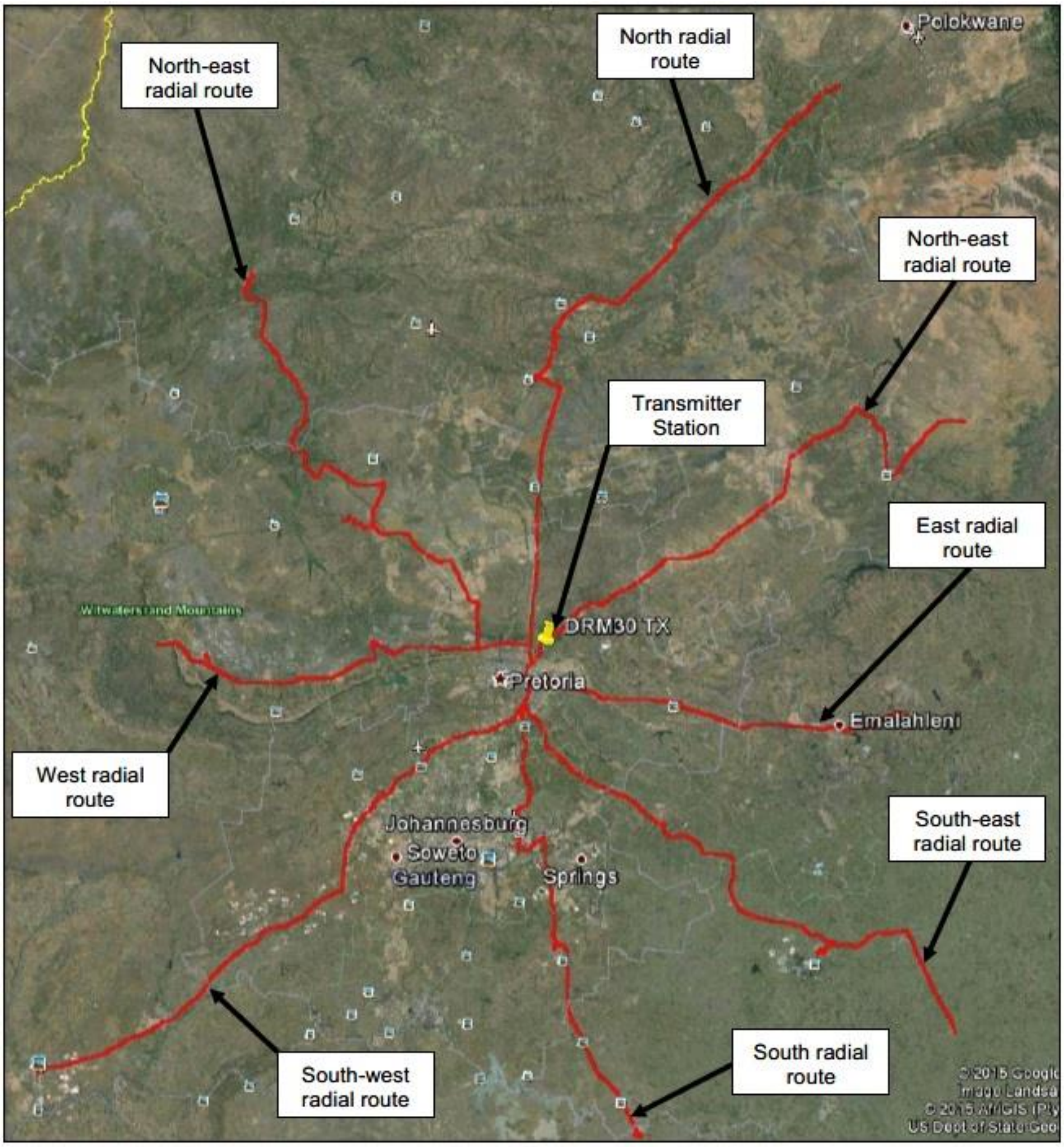


TABLE 8

**Drive-By Measurement Routes**

| Route No. | Dates measured | Description | Objective |
|---|---|---|---|
| 1 | 2015/03/16<br>2015/09/22 | Kameeldrift – N1 North – Bela Bela - R101- Modimolle – N1 North – Mookgopong – Mokopane. - Polokwane (Total Distance from transmitter station: 210 km) | Measure signal on N1 north route, Bela Bela, Modimolle, Mookgopong, N1 north route between Kameeldrift and Polokwane. |
| 2 | 2015/03/17<br>2015/09/23 | Kameeldrift – N4 East – Bronkhorstspruit – N4 East – Emalahleni – Middelburg.<br>(Total Distance from transmitter station: 112 km) | Measure signal on N4 east route, Bronkhorstspruit, Emalahleni, N4 east route between Kameeldrift and Middelburg. |
| 3 | 2015/03/18<br>2015/09/25 | Kameeldrift – N1South – R21 – OR Tambo International Airport – Boksburg – Benoni – R23 – Heidelberg – N3 South – Villiers.<br>(Total Distance from transmitter station: 154 km) | Measure signal on N3 south route, OR Tambo International, Benoni, Heidelberg, N3 south route between Kameeldrift and Villiers. |
| 4 | 2015/03/19<br>2015/09/28 | Kameeldrift – N4 West – Brits – Rustenburg.<br>(Total Distance from transmitter station: 124 km) | Measure signal on N4 west route, Brits, Rustenburg, N4 west route between Kameeldrift and Rustenburg. |
| 5 | 2015/03/23<br>2015/09/29 | Kameeldrift – R573 – Moloto – Kwamhlanga – Kwaggafontein – Marblehall – N11 – Groblersdal – R33 – Tafelkop – Luckau.<br>(Total Distance from transmitter station: 151 km) | Measure signal on R573 north-east route, Moloto, Kwamhlanga, Kwaggafontein, Marblehall, N11, Groblersdal, R33, Tafelkop, R573 north-east route between Kameeldrift and Luckau. |
| 6 | 2015/03/24<br>2015/09/30 | Kameeldrift – N1 South – R50 – Delmas – R50 – Leandra – N17 - Trichardt – Secunda Mall – N17 – Bethal – R35 – Morganzon.<br>(Total Distance from transmitter station: 176 km) | Measure signal on R50 south-east route, Delmas, R50, Leandra, N17, Trichardt, Secunda, N17, Bethal, R35, south-east route between Kameeldrift and Morganzon. |
| 7 | 2015/03/25<br>2015/10/01 | Kameeldrift – N1 South – N14 – Krugersdorp – R28 – N12 – Potchefstroom – N12 – Klerksdorp.<br>(Total Distance from transmitter station: 212 km) | Measure signal on N14 south-west route, Krugersdorp, R28, N12, Potchefstroom, N12, Klerksdorp, south-west route between Kameeldrift and Klerksdorp. |
| 8 | 2015/03/26<br>2015/10/02 | Kameeldrift – N4 West – R80 – Soshanguve – Jericho – R511 – R510 – Thabazimbi.<br>(Total Distance from transmitter station: 152 km) | Measure signal on R511 north-west route, R80, Soshanguve, Jericho, R511, R510, Thabazimbi, north-west route between Kameeldrift and Thabazimbi. |

# 7 Measurement analysis

Measurement analyses were conducted with the objective to determine and verify the potential benefits of the DRM30 technology as a potential radio broadcast platform. The measurement analysis and findings described in this section include both the analysis and findings on both the antenna systems (Broadcom and KinStar) as well as coverage measurement results measured on both antenna systems.

## 7.1 Correction factor

This section provides a brief explanation of the Correction Factor (CF) requirement as well as the calculation thereof.

The field strength parameter (in dBµV/m) is used in radio propagation coverage predictions and analysis. Measurement tools measure signal strength levels (in dBm or dBµV). Determining the field strength value from the measured signal strength value require the antenna correction factor to be calculated and included with the gains and losses of all the elements of the measurement system including the antenna dipole factor (DF). The unit used for field strength measurement is Volt per meter (V/m) or micro-volt per meter (µV/m).

The total correction factor is determined by reading the antenna dipole factor from the antenna factor graph and also by including all the measurement system gains and losses. This correction factor could either be included in the measurement system setup configuration, or added afterwards during the analysis of the measurement values. The formula used is indicated below and the measurement system correction factor is shown in Table 9.

**Formula**:

| | |
|---|---|
| CF = | Antenna Factor - G + Feeder insertion Loss + Connector's Insertion loss + Height Loss Correction factor ($L_h$) |

TABLE 9

**Correction factor of the R&S®HE010E antenna system for Band 6 (MF) at 1440 kHz**

| No. | Description | Factor (dB) | Comments |
|---|---|---|---|
| 1 | Antenna Factor for R&S®HE010E @ 1440 kHz | 10.3 | Dipole Factor is added to the measured signal strength measurement unit (dBµV) value to enable it to be converted to a field strength measurement (dBµV/m) unit value |
| 2 | R&S®HE010E antenna gain | 0 | Gain to be subtracted from measurement |
| 3 | Coaxial cable & connector loss | 0 | Loss to be added to measurement |
| 4 | Antenna height loss correction factor | 0 | Loss to be added to measurement |
| | **Total Correction Factor** | 10.3 | Total value of correction factor be added to the measured signal strength measurement value |

The information provided by Rhode & Schwarz state that the antenna factor for the R&S®HE010E active antenna system already included the gains and the losses in the measurement result.

### 7.2 Basic antenna radiation analysis

Antenna directivity analysis was conducted by using both the predicted as well as the measured field strength values for correlation purposes. Analyses were conducted on both the Broadcom and KinStar antenna systems. Special notice should be taken that an analogue narrow band pilot signal was used during the measurement exercise.

Correlation results are presented graphically in Figures 15 to 19. Details of the 32 measurement test points are tabled in Table 16 in Appendix A.

Findings on the analysis of the correlated results can be summarized as follow:

1. Predicted field strength values of the Broadcom antenna and the KinStar antenna were found to be the same on all 32 test points;
2. Measured field strength values were found in most cases to be higher than predicted. (Overall average of 32 measurement values indicated results higher than predicted by 7.7 dB for the Broadcom antenna and 6.6 dB for the KinStar antenna);
3. The maximum difference between measured and predicted values for both antennas (Broadcom and KinStar) was located on the 90º radial at a distance of 5 km from the transmitter station as indicated in Figure 18;
4. Averaging the predicted and measured values per radial and analysing the results provided some indication of the antenna directivity for both antennas (Broadcom and KinStar) as indicated in Figure 19;
5. The measured horizontal radiation pattern and predicted radiation pattern were found to be comparable except for the measurement values which measure slightly higher than predicted;
6. The Broadcom antenna measurements were found in most cases to be higher than the KinStar antenna measurements;
7. The KinStar antenna measured higher than the Broadcom antenna on the 45º radial at a distance of 1km from the transmitter's station as indicated in Figure 16. The KinStar antenna also measured higher than the Broadcom antenna on both the 90º and 225º radials, at a distance of 2 km from the transmitter station which is indicated in Figure 17;
8. The KinStar antenna measured lower than predicted on the 135º radial at a distance of 5km from the transmitter station as indicated in Figure 18;
9. The average difference in values between the Broadcom antenna and the KinStar antenna indicate that the Broadcom antenna measured higher than the KinStar antenna as indicated in Figure 19;
10. Measurements in the future should include both an analogue pilot signal as well as a DRM30 wide band signal;
11. Future measurements should include spectrum graphs as well.

FIGURE 15

**Measured field strength at test points located 0.5 km from the transmitter station in 8 radial directions**

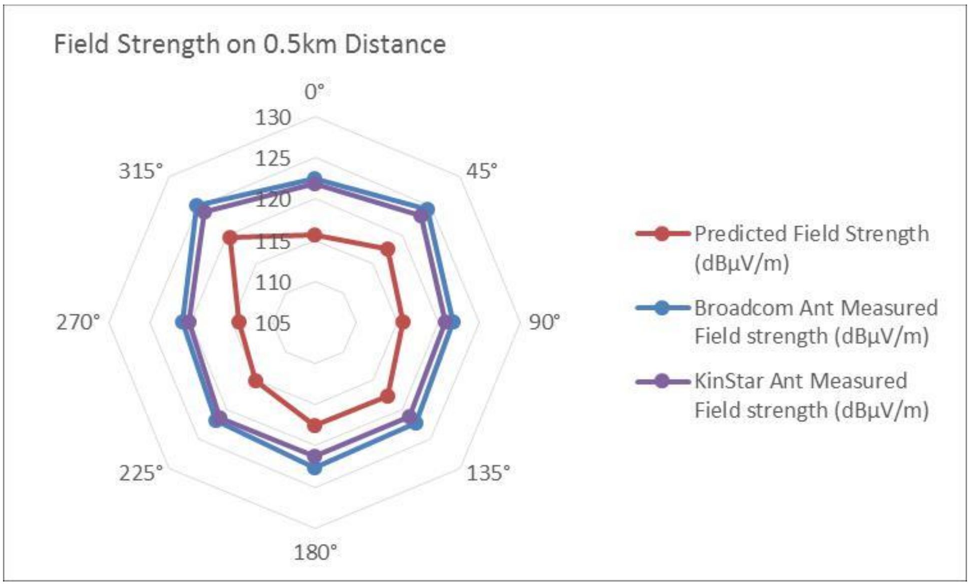



FIGURE 16

**Measured field strength at test points located 1 km from the transmitter station in 8 radial direction**

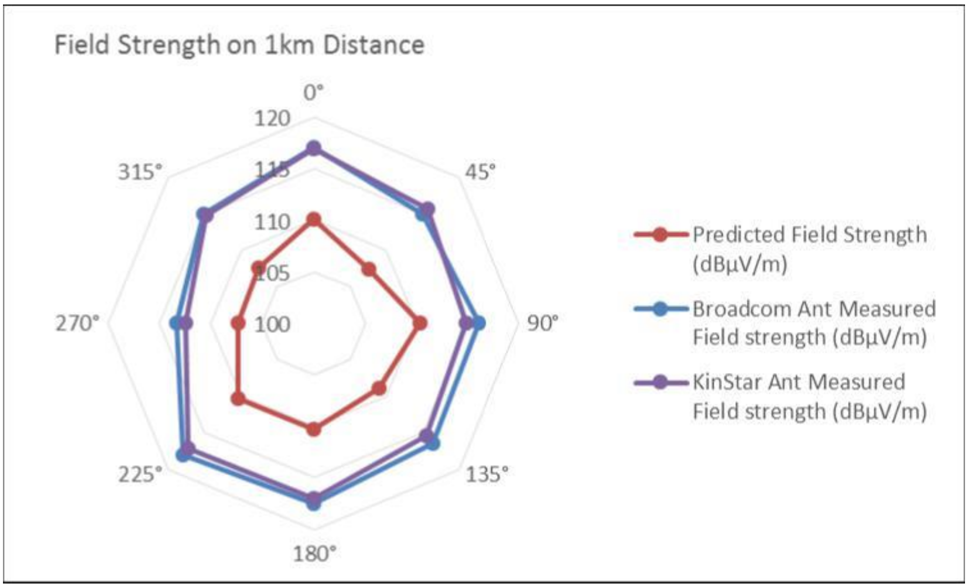


FIGURE 17

**Measured field strength at test points located 2 km from the transmitter station in 8 radial directions.**

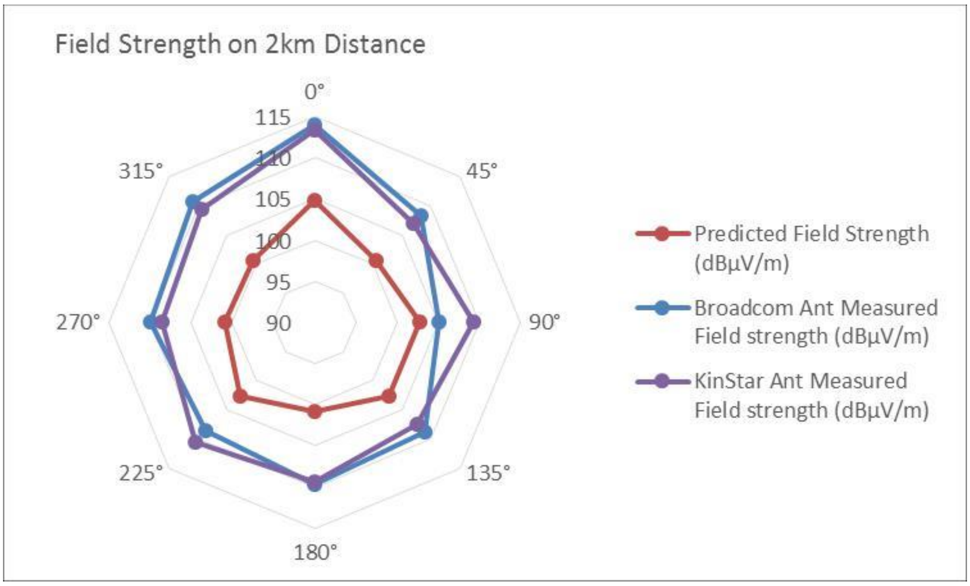



FIGURE 18

**Measured field strength at test points located 5 km from the transmitter station in 8 radial directions**

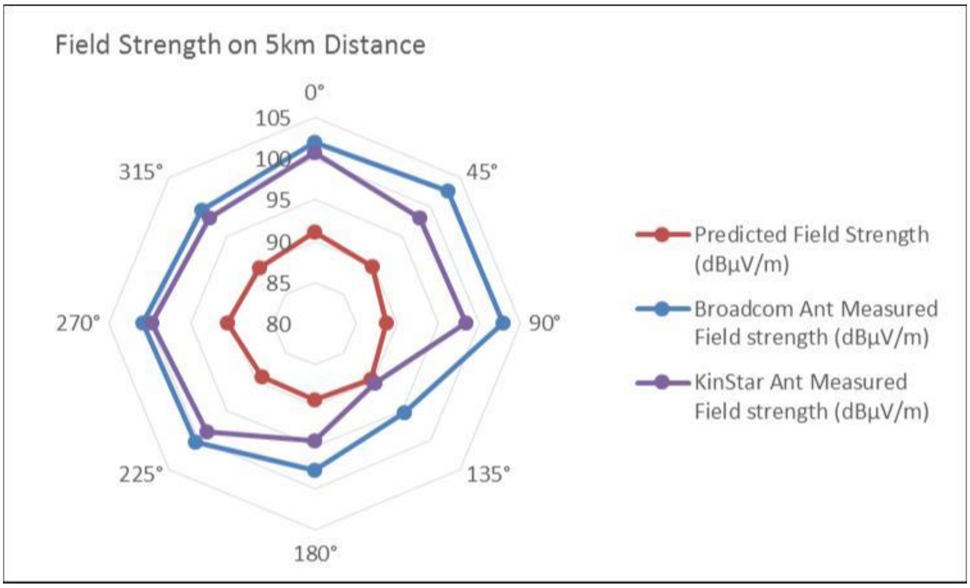
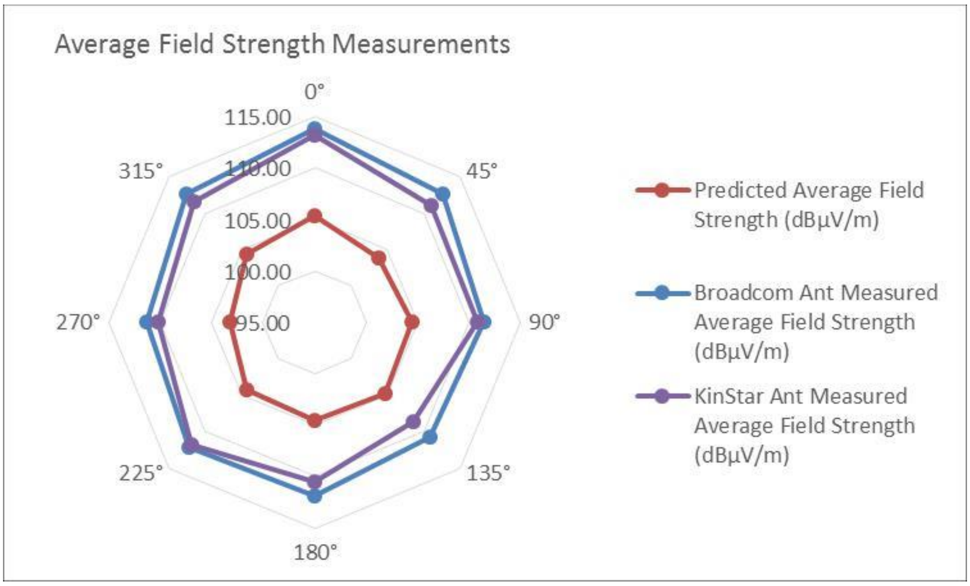


FIGURE 19

**Calculated average field strength for all test point measurements which include all 4 distances (0.5 km, 1 km, 2 km and 5 km) from the transmitter station on each of the 8 radials**




### 7.3 Coverage analysis

Coverage analyses require the measurement values to be correlated with the predicted values as well as with the ITU specified performance indicators.

#### 7.3.1 Background on ground-wave and sky-wave propagation

When services are broadcasted on medium frequency (MF) radio signals, the radio signals are being propagated in all directions. The MF radio signals can however be grouped and defined in two main grouping waves, namely ground-wave and sky-wave. Refer to figure 1 for a graphical representation of ground-wave coverage, skip zone and sky-wave coverage.

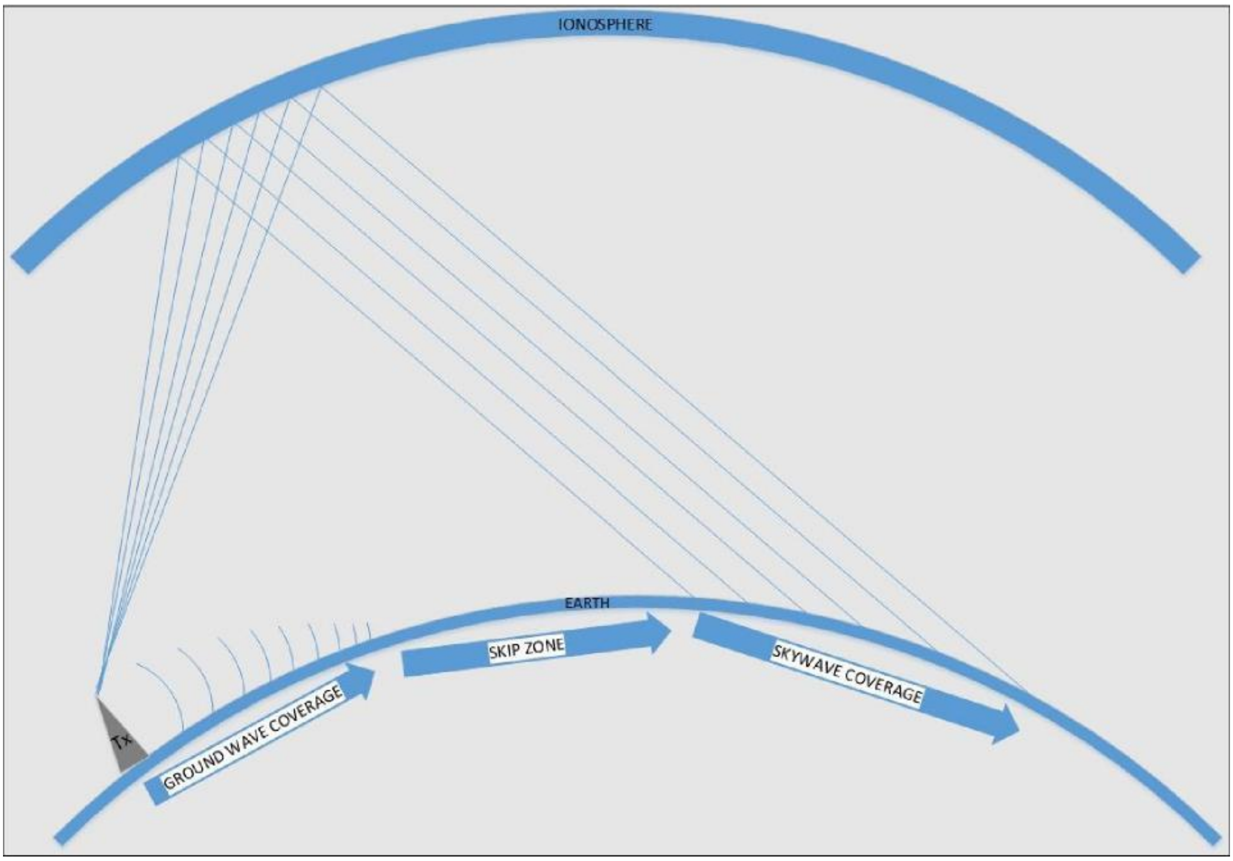
Ground-wave radio propagation occurs as the signal propagates from the transmitter in close proximity to the ground. Propagated ground-wave radio signals also tend to follow the curvature of the earth. The propagated ground-wave also cause currents to be induced in the earth’s surface, resulting in the “slowing down” of the propagated wave which impacts the propagation path, causing it to follow the curvature of the earth and enable it to travel beyond the horizon. Ground-wave propagation is more dominant during the day-time.

Since the transmitted radio wave is propagated in all directions, some of the waves travel either directly via ground-waves, or are reflected from the earth’s surface skywards. The ionosphere is a region of the upper atmosphere, from about 80 km to 1 000 km in altitude, where neutral air is ionized by solar photons and cosmic rays. When high frequency signals enter the ionosphere obliquely, they are back-scattered from the ionized layer as scatter waves as indicated in Figure 20. If the mid-layer ionization is strong enough, compared to the signal frequency, a scatter wave can exit the bottom of the layer earthwards as if reflected from a mirror. Earth's surface (ground or water) then diffusely reflects the incoming wave back towards the ionosphere. The signal may effectively "bounce" or "skip" between the earth and ionosphere two or more times (multi-hop propagation). Under specific atmospheric conditions (mainly at night) more radio signals are back-scattered from the ionosphere resulting in more of these signals to be returned to earth. These signals are termed sky-waves. The impact of sky-wave propagation is therefore more noticeable at night-time.

The sky-wave propagation becomes significant between the periods after sunset up to sunrise the next morning. Although sky-wave propagation has the potential to enable large distances to be covered under certain atmospheric conditions, it unfortunately also has the ability to have a destructive impact on the ground-wave. This is mainly due to the reflected sky-wave causing interference with the original propagated ground-wave. This is called Sky-wave interference. The Sky-wave interference area is called the Sky-wave interference zone.

FIGURE 20

**Ground-wave coverage, skip zone and sky-wave coverage**




### 7.3.2 Ground-wave and sky-wave predictions

The prediction of field strength for digital sound broadcasting systems is covered in Recommendation ITU-R P.1321. This ITU-R Recommendation also refers to two other Recommendations: Recommendation ITU-R P.368-7 for ground-wave predictions and Recommendation ITU-R P.1147 for Sky-Wave predictions.

Recommendation ITU-R P.368-7 is a calculation model that is specifically used to calculate the fields strength achieved through ground-wave propagation, which is then used for ground-wave coverage predictions.

Recommendation ITU-R P.1147 is a calculation model that is specifically used to calculate the field strength achieved through sky-wave propagation, which is then used to predict sky-wave coverage.

### 7.3.3 Ground conductivity data

Ground conductivity data (.sol file) was obtained by using the ITU Digitized World Map (IDWM2Raster) software. The conductivity and permittivity values were imported into an ICS

Telecom planning tool in a clutter file (.sol) format and used as a clutter layer. This enabled the planning tool to simulate ground-conductivity to ensure it is also included as a variable in coverage predictions.

### 7.3.4 Predicted ground-wave coverage area

Notice should be taken that the ground-wave predictions on both antennas were conducted by using the antenna patterns of an isotropic antenna.

The ground-wave coverage area was predicted by using the ITU-R P.368-7 propagation prediction model. This prediction model excluded man-made noise such as bridges, high voltage overhead cables, tall buildings etc. The predicted DRM30 signal coverage areas with the Main Service Channel (MSC) modulated on 16QAM and 64QAM digital modulation schemes are indicated in Figure 21.

The relation between the predicted analogue and digital coverage areas (16QAM & 64QAM) based on the same transmit power (10kW) is indicated in Table 10 and Figure 22.

Differences in predicted coverages areas can be noted as follows:

– DRM30 configured on 16QAM modulation (protection 0, average code rate 0.5) provides a more robust signal with a larger area coverage but with less capacity for content;

– DRM30 configured on 64QAM modulation (protection 0, average code rate 0.5) provides a less robust signal with a slightly smaller coverage area but more capacity for content;

– Analogue MW covers the smallest area.

TABLE 10

**Predicted Area Coverage**

| TX output power | Total area covered | Modulation | Field strength |
|---|---|---|---|
| 10kW | 87 710 km$^2$ | 16QAM | 33.1 dBµV/m |
| 10kW | 51 195 km$^2$ | 64QAM | 38.6 dBµV/m |
| 10kW | 6 197 km$^2$ | AM | 60 dBµV/m |

FIGURE 21

**Predicted DRM30 ground-wave coverage areas (16QAM & 64QAM)**

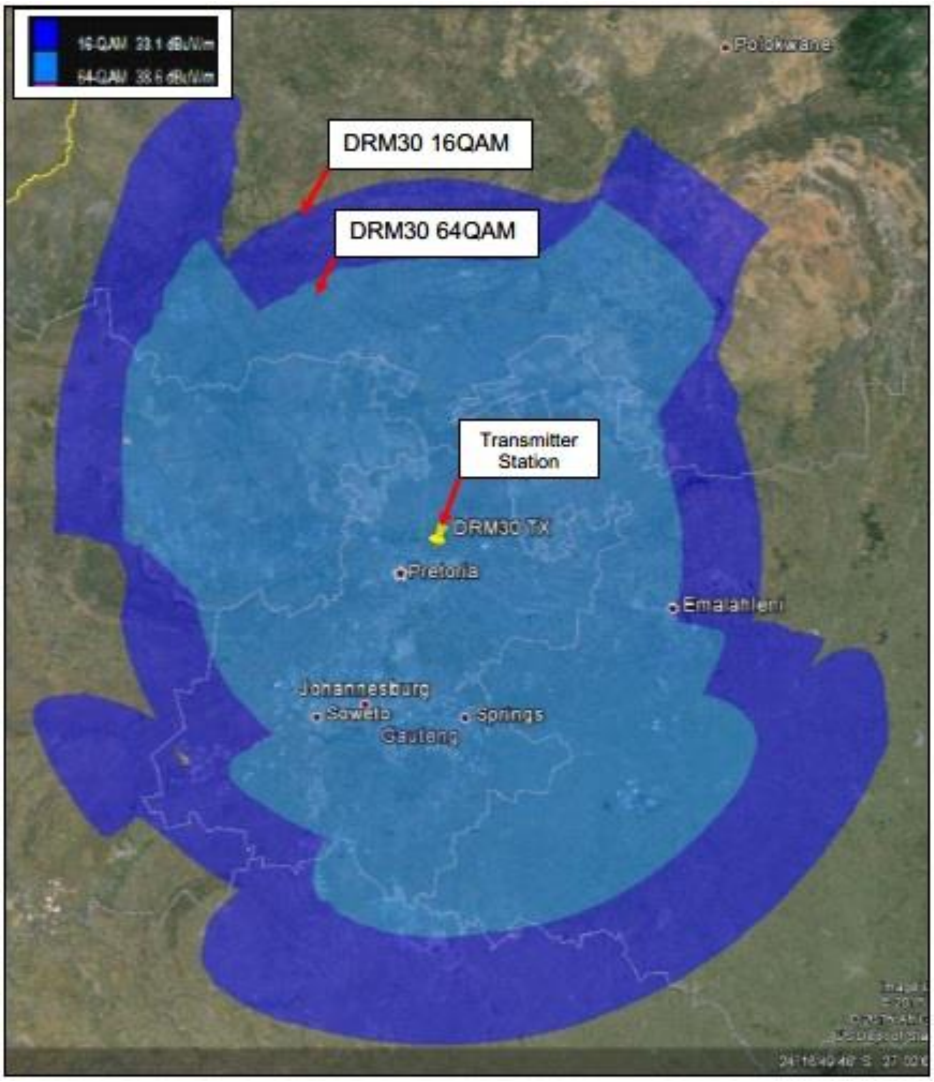
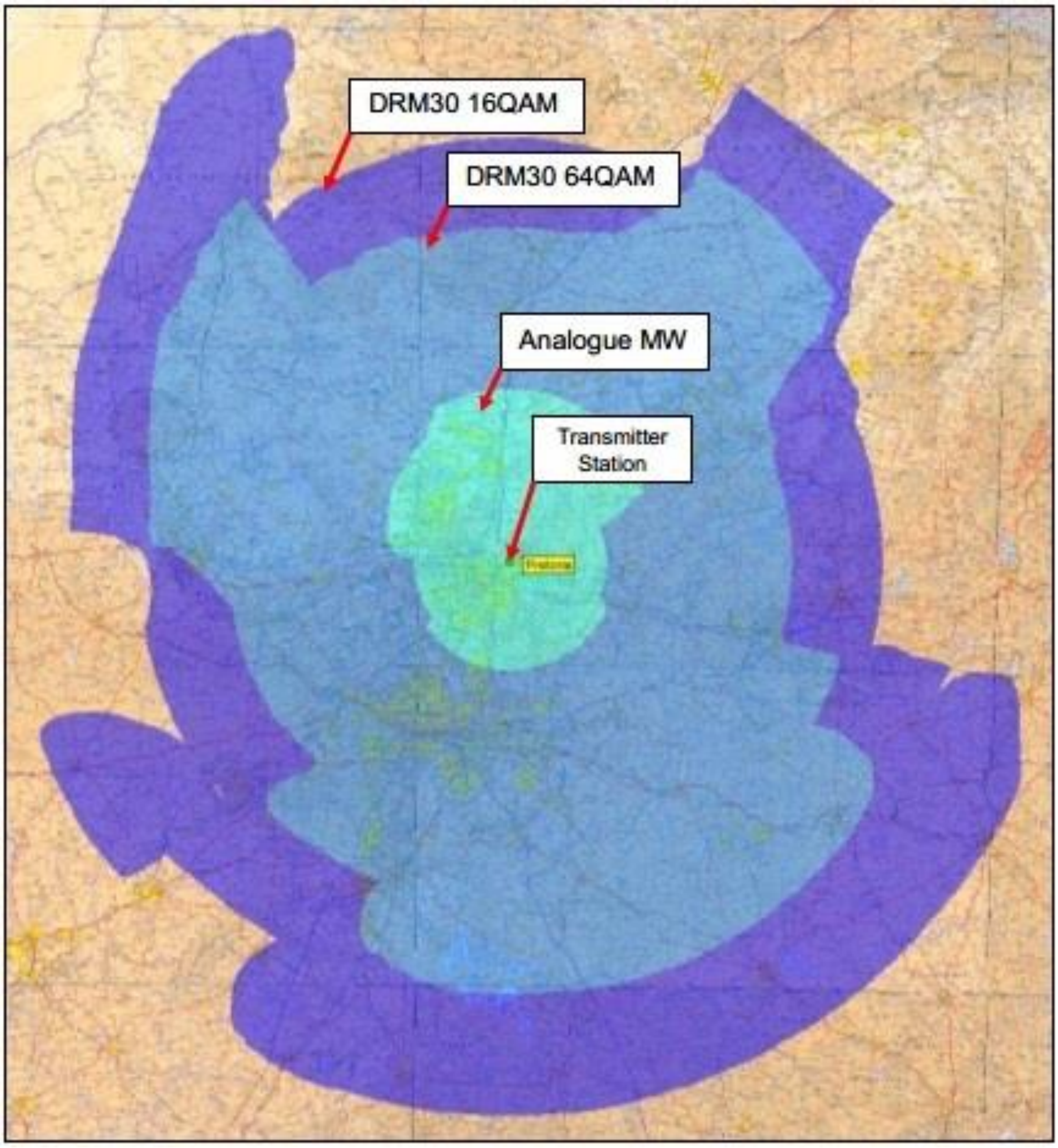


FIGURE 22

**Predicted comparison between 10kW analogue MW and 10kW DRM30 (16 & 64QAM modulation)**



### 7.3.5 Ground-wave analysis

Ground-wave measurements were conducted in eight radial directions in the predicted ground-wave coverage area. Eight radial routes were measured using both drive-by and static point measurement methods. Measurements routes in the eight radial directions are indicated in Figure 23.

FIGURE 23

**Measurement routes in eight radial directions located in the DRM30 coverage area**

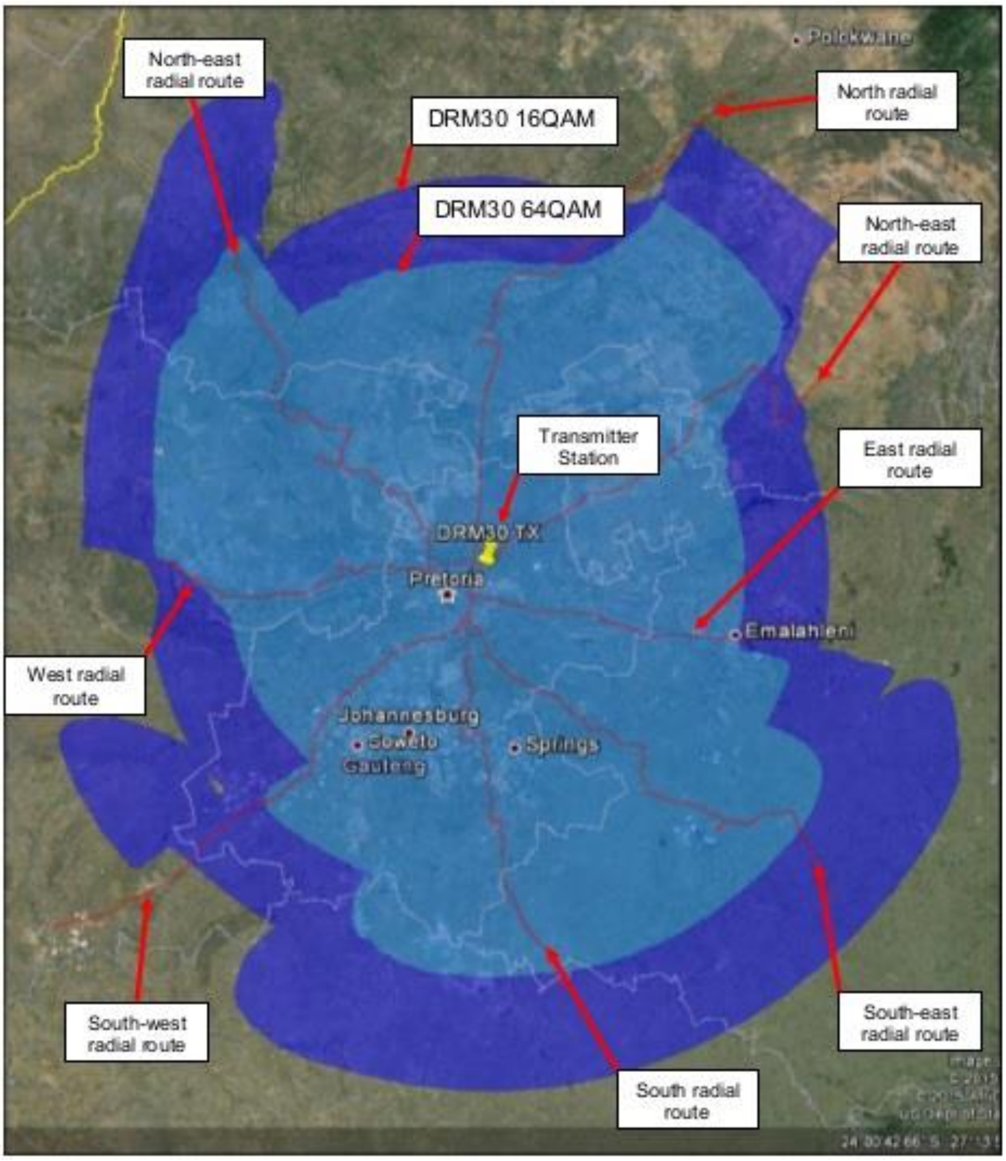
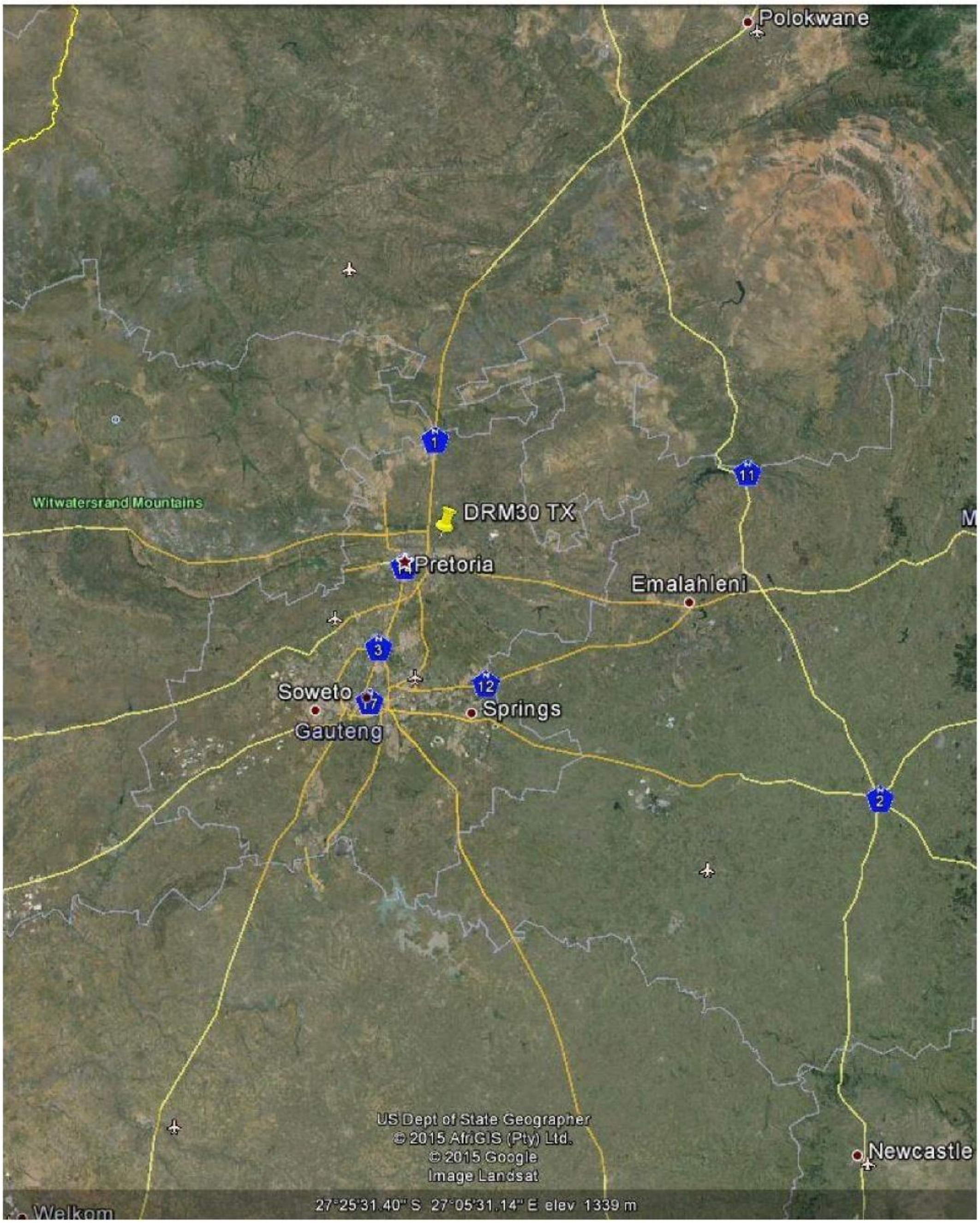


FIGURE 24

**Map indicating area around transmitter station**




### 7.3.5.1 Measurement correlations – ground-wave

One of the objectives of the measurement trial was the evaluation of actual measured coverage versus the predicted coverage. This was achieved by importing Drive-By measurement values into an ICS planning tool and correlating the field strength measurement values with the predicted field strength values. The number of Drive-By measurement values which was imported for the Broadcom antenna was 580 477 and 619 718 for the KinStar antenna.

Correlation results were analysed and the analysis results provided in the distribution spread graphs (graph 8 and graph 9) which provide an indication of the number of values deviating in a predetermined margin (dB's) between the measured and predicted values. Analysis result values are also tabulated in Tables 11 and 12.

Analysis of the field strength correlation results between the measured Broadcom antenna and the predicted values are summarized as follow:

– 177 647 (30.6%) field strength measurement values correlated exactly with the predicted values;
– 295 587 (50.9%) field strength measurement values correlated within a ±3 dB margin from the predicted field strength measurement values;
– 335 477 (57.8%) field strength measurement values correlated within a ±6 dB margin from the predicted field strength measurement values;
– 346 680 (59.7%) field strength measurement values were above 0dB which is an indication of an under-prediction.

Analysis of the field strength correlation results between the measured KinStar antenna and the predicted values are summarized as follow:

– 366 883 (59.2%) field strength measurement values correlated exactly with the predicted values;
– 594 392 (95.9%) field strength measurement values correlated within a ±3 dB margin from the predicted field strength measurement values;
– 613 372 (99.0%) field strength measurement values correlated within a ±6 dB margin from the predicted field strength measurement values.

Comparison of the field strength correlation results between the Broadcom antenna and the KinStar antenna can be summarized as follow:

– The total Drive-By measurements conducted on the Broadcom antenna was 580 477 which are 39 098 measurements less (6.34%) than the 619 718 measurement values measured on the KinStar antenna;
– The number of the measurement values which correlated exactly with the predicted values on the Broadcom antenna was 177 647 (30.6%) measurement values and for the KinStar antenna was 366 883 (59.2%) measurement values;
– Comparison of the distribution graphs (Figures 25 and 26) provide a clear indication that the measurement values of the KinStar antenna correlated better with the predicted values compared to correlations conducted on the Broadcom antenna.

The findings from studying the correlated field strength distribution graphs in Figures 25 and 26 and the tabulated results in Tables 11 and 12 can be summarized as follows:

– The planning tool was capable to conduct field strength coverage predictions more accurately on the KinStar antenna compared to predictions conducted on the Broadcom antenna;
– The planning tool indicated an under-prediction on the Broadcom antenna;
– Planning of the DRM30 transmitter technology can be conducted successfully with the aid of the ATDI ICS TELECOM planning tool.

FIGURE 25

**Correlation distribution graph indicating deviation between predicted and measured field strength values for Broadcom antenna.**

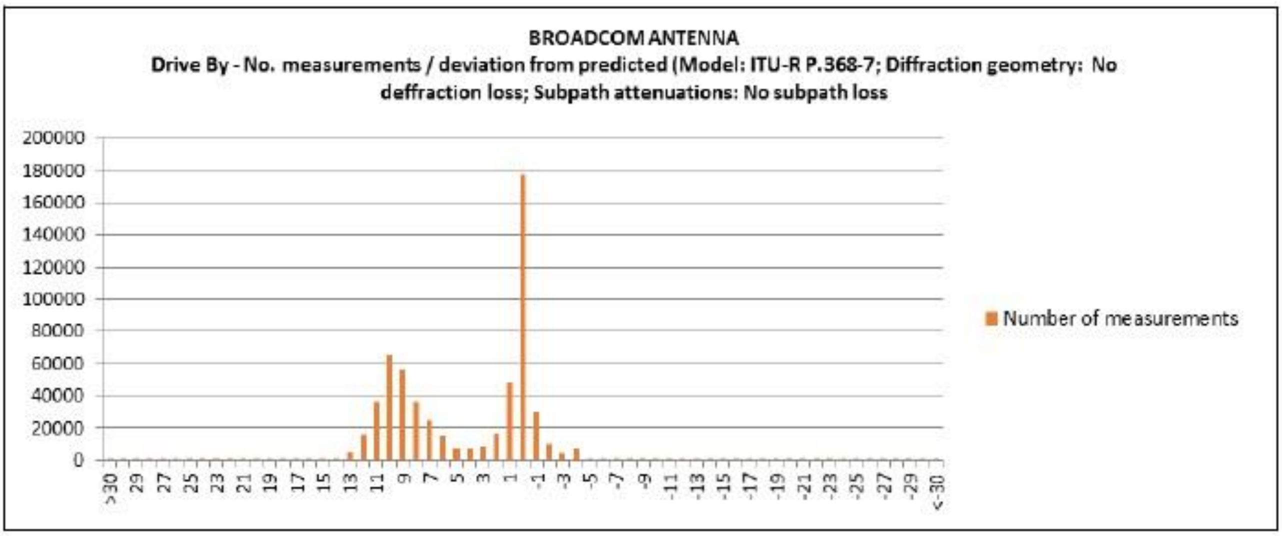



TABLE 11

**Deviation from prediction for the Broadcom antenna.**

| Deviation from Predicted summary | | | |
|---|---|---|---|
| No. Measurements = 0dB | 17 7647 | 30.6 | % |
| No. Measurements < 0dB | 56 150 | 9.7 | % |
| No. Measurements > 0dB | 346 680 | 59.7 | % |
| No. Measurements within 1dB | 256 425 | 44.2 | % |
| No. Measurements within 2dB | 283 240 | 48.8 | % |
| No. Measurements within 3dB | 295 587 | 50.9 | % |
| No. Measurements within 4dB | 311 292 | 53.6 | % |
| No. Measurements within 5dB | 320 231 | 55.2 | % |
| No. Measurements within 6dB | 335477 | 57.8 | % |
| No. Measurements <>6dB | 245 000 | 42.2 | % |
| No. Measurements within 30dB | 580 435 | 100.0 | % |
| No. Measurements <>20dB | 42 | 0.0 | % |
| No. Total Measurements | 580 477 | 100.0 | % |

FIGURE 26

**Correlation distribution graph indicating deviation between predicted and measured field strength values for KinStar antenna**

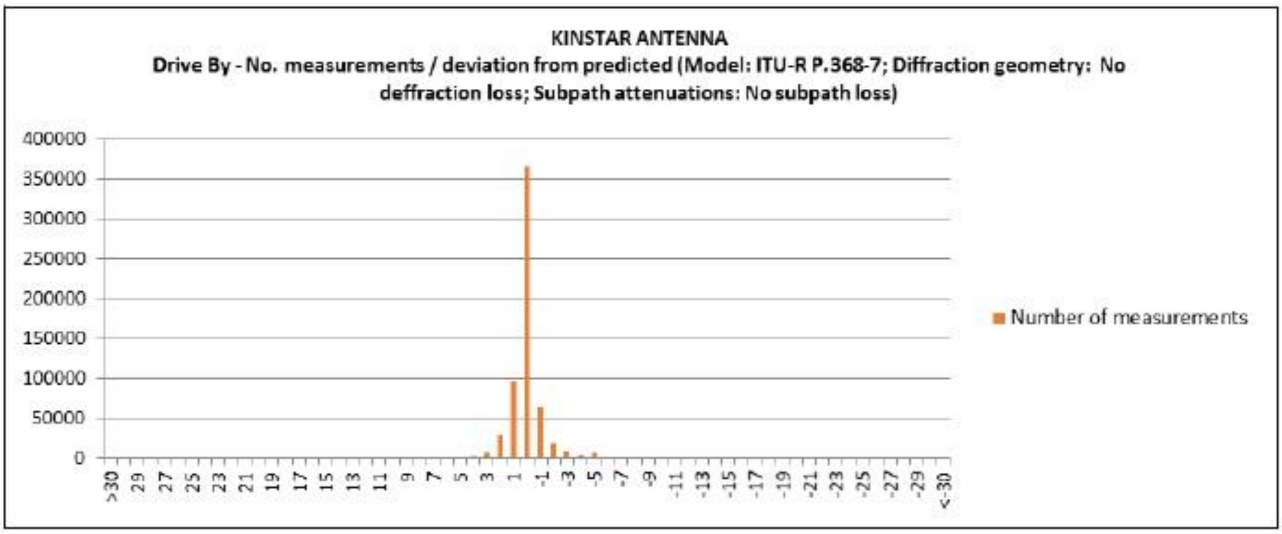



TABLE 12

**Deviation from prediction for the KinStar antenna**

| Deviation from Predicted summary | | | |
|---|---|---|---|
| No. Measurements = 0dB | 366 883 | 59.2 | % |
| No. Measurements < 0dB | 112 201 | 18.1 | % |
| No. Measurements > 0dB | 140 634 | 22.7 | % |
| No. Measurements within 1dB | 527 451 | 85.1 | % |
| No. Measurements within 2dB | 577 434 | 93.2 | % |
| No. Measurements within 3dB | 594 392 | 95.9 | % |
| No. Measurements within 4dB | 601 969 | 97.1 | % |
| No. Measurements within 5dB | 611 674 | 98.7 | % |
| No. Measurements within 6dB | 613 372 | 99.0 | % |
| No. Measurements <>6dB | 6 346 | 1.0 | % |
| No. Measurements within 30dB | 619 674 | 100.0 | % |
| No. Measurements <>20dB | 44 | 0.0 | % |
| No. Total Measurements | 619 718 | 100.0 | % |

### 7.3.5.2 Ground-wave performance analysis (DRM30)

Ground-wave measurements for Broadcom antenna and KinStar antenna were conducted in eight radial directions and the measured parameters statistically analysed per distance from the transmitter, which ranged between 114 km to 207 km, depending on the service quality reception experienced on the relevant route.

Statistical measurement results are graphically presented in Appendix B, as Figures 56 to 71, for the Broadcom antenna, and in Appendix C as Figures 72 to 81, for the KinStar antenna. Graphical presentation of the results include measurements conducted on all radial directional routes and on two different modulation settings (16QAM & 64QAM). This was achieved by conducting measurements on a lower modulation setting (16QAM) driving in a direction away from the transmitter and when returning to the transmitter, conducting measurements on a higher modulation setting (64QAM). Measurement results on the eight radial routes on the Broadcom antenna are also indicated in Figures 56 to 71 in Appendix B and the results on the KinStar antenna in Figures 72 to 81 in Appendix C.

Analogue AM measurements were also conducted on two radial routes (north radial and south radial) on the KinStar antenna; this was done by only driving in a direction away from the transmitter station. The graphical representation of the measurement results on the two radial routes are indicated in Figures 92 and 93 in Appendix E.

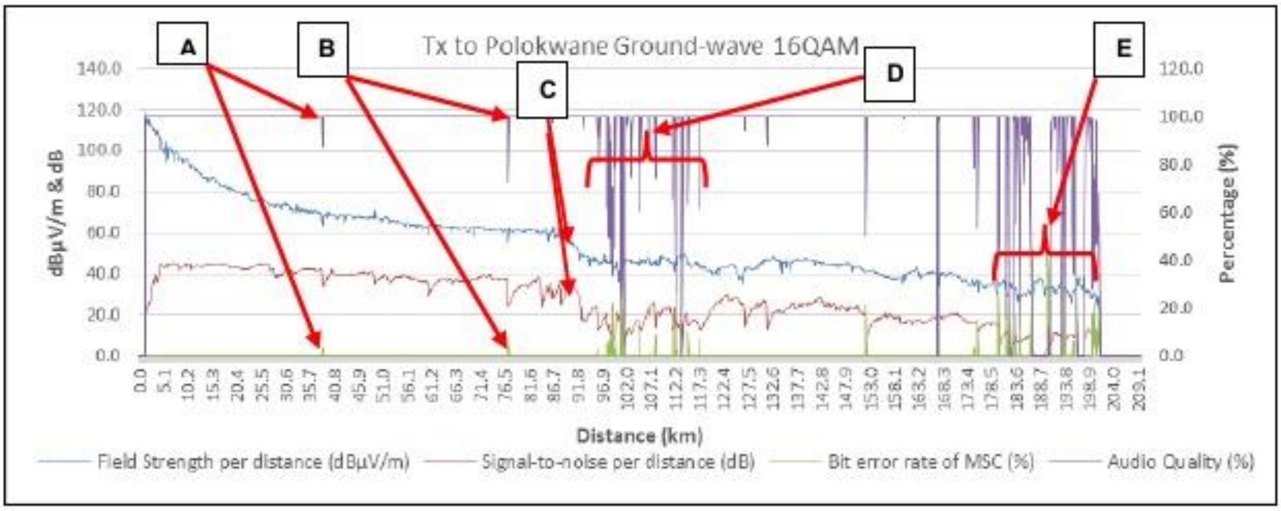
Describing each one of the radial routes in detail would become quite diffusive which therefore resulted in the detailed explanation on the analysis of one of the routes measured (north radial route). The other graphs could then be studied as required to obtain an indication of the ground-wave performance on the specific selected route.

The route (north radial route) which was chosen to discuss the ground-wave analysis is the route from the transmitter station (located in Pretoria) to Polokwane (16 QAM modulation) and back to the transmitter station (64QAM modulation). Graphical presentation of the measured parameter values on the Broadcom antenna measurement route are indicated in Figure 27 (16QAM) and Figure 28 (64QAM). Graphical representation of the measured parameter values on the KinStar antenna measurement route are indicated in Figures 29 and 30.

The analogue AM measurements are presented in Figure 31 and were only conducted on the KinStar antenna.

FIGURE 27

**DRM30 measurements on route from transmitter to Polokwane (16QAM) – Broadcom Antenna**




Studying Figure 27 (16QAM) the measurement parameters indicate the following:

– Measurement results indicate a slight decrease in audio quality (purple graphical line) and signal to noise (S/N) ratio (red graphical line) for a short distance, at the tollgate ± 37 km from the transmitter station (Indicated with label A in Figure 27).

– Measurement results indicate a larger decrease in audio quality (purple graphical line) and S/N (red graphical line) for a short distance when passing under a bridge ± 76 km from the transmitter station (Indicated with label B in Figure 27).

– Measurement results indicate a significant decrease in field strength (blue graphical line) as well as the S/N (red graphical line), starting at a distance of ± 90km from the transmitter station (Indicated with label C in Figure 27).

– The route to the north approached a mountainous terrain (Indicated with label D in Figure 27,) which resulted in a decrease in the field strength, decrease in S/N, increase in BER and degradation of audio quality. Degradation of the signal in the mountainous terrain was due to various factors which included signal propagation path obstructions due to the terrain and also changes in the ground-conductivity which could clearly be noticed when correlated with the planning tool.

– Both the field strength and the S/N values continued to degrease as the distance from the transmitter increased.

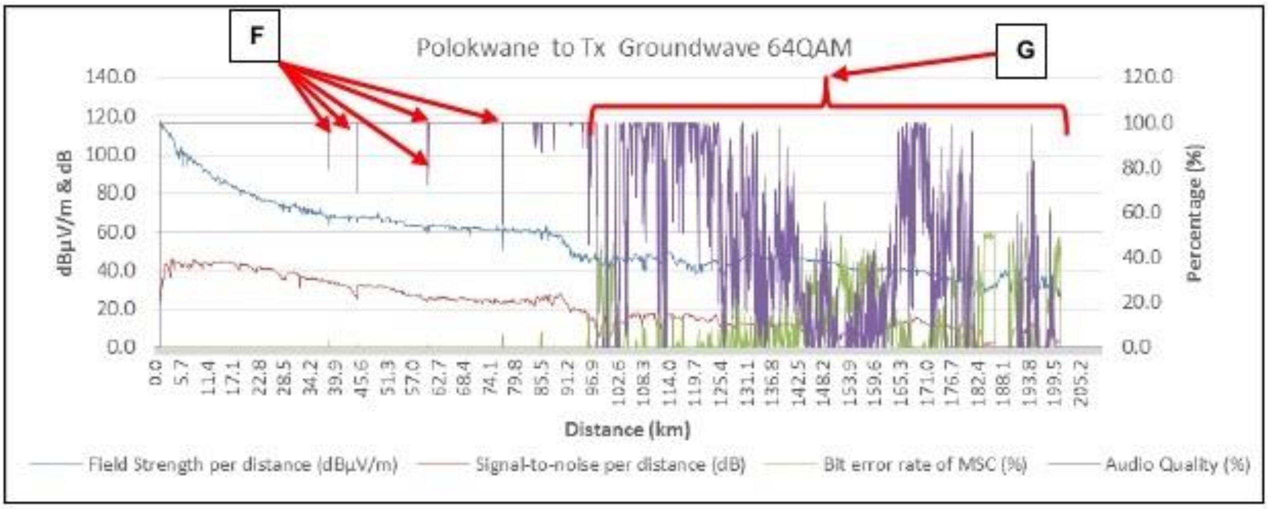
– Exiting the mountainous terrain resulted in an improvement of the field strength and S/N, resulting in the reduction of BER and improvement of audio quality. The overall quality of the signal was good and stable till another mountainous terrain was approached and entered.

– Entering of the mountainous terrain at a distance of ± 180 km from the transmitter station resulted in a decrease of the field strength,

– Decrease in S/N, increase in BER and decrease of the audio quality (Indicated with label E in Figure 27). This was as a result of a combination of factors which included the distance from the transmitter, change in ground-conductivity and propagation path obstruction by mountains. The quality of the signal kept on changing till complete signal failure a few kilometres before the Polokwane town which is located at a distance ±200 km from the transmitter station.

FIGURE 28

**Route from Polokwane to transmitter (64QAM) – Broadcom Antenna**




Studying Figure 28 (64QAM) the measurement parameters indicate the following:

– When the route measurement from Pretoria to Polokwane was completed the modulation setting was changed from the rugged 16QAM modulation setting, to the less-rugged 64QAM modulation setting. Measurements were then conducted on the same route in an opposite direction from Polokwane to the transmitter station located in Pretoria;

– Although the field strength did not change significantly on the 64QAM setting (compared to the 16QAM setting) the reduction on the S/N levels was significant, resulting in an increase of the BER and decrease in the audio quality (Indicated with label G in Figure 28);

– The route from the north approached a mountainous terrain (Indicated with label G in Figure 28) which resulted in a decrease in the field strength, decrease in S/N, increase in BER and degradation of audio quality. Degradation of the signal in the mountainous terrain was due to various factors which included signal propagation path obstructions due to the terrain and also changes in the ground-conductivity which could clearly be noticed in the planning tool;

– Measurement results indicate a slight decrease in audio quality (purple graphical line) and S/N (red graphical line) for a short distance, at tollgates and when passing under a bridges (Indicated with label F in Figure 28);

– All measurement parameters improved when the mountainous terrain changed to non-mountainous terrain on the route towards the transmitter station.

Comparison between the 16QAM and 64QAM Broadcom antenna measurement results indicated the following:

– Comparisons between the measurement results on 16QAM modulation (Figure 27) and 64QAM (Figure 28) indicate the field strength to be more-or-less similar on both graphs, but with a significant decrease in S/N values, increase in BER and the degradation of the audio quality, especially in the area marked “G” on Figure 28;

– The less rugged modulation setting resulted in a severe degradation of the signal on the route located between ± 97 km to 200 km from the transmitter station. Recovery of a stable signal was only measured ±97 km from the transmitter station.

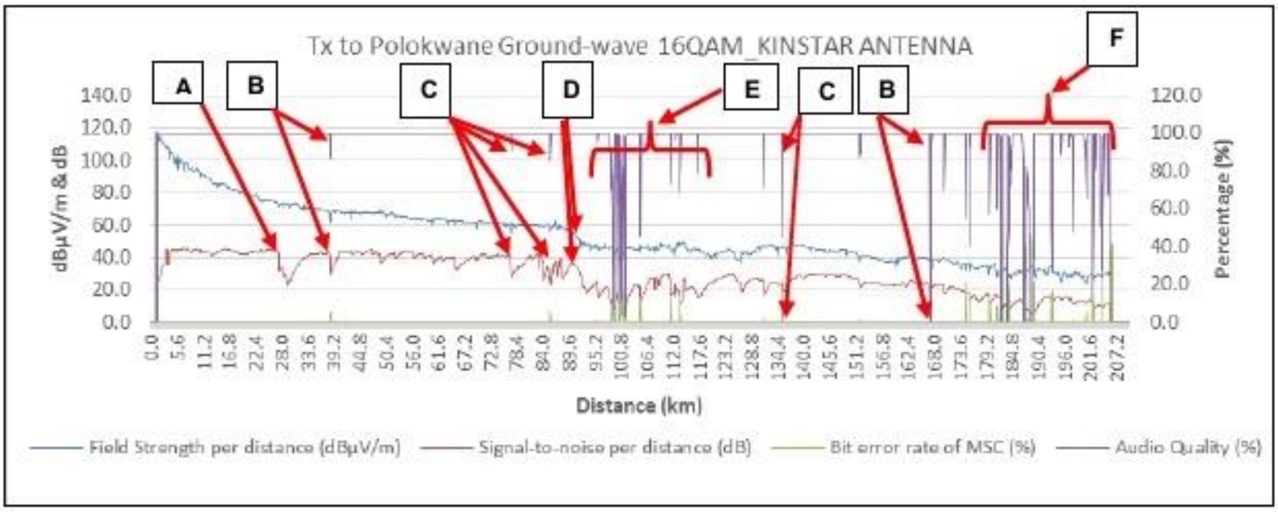
– The combination of a less-rugged modulation setting (64QAM), mountainous terrain and poor ground-conductivity resulted in signal failure between Polokwane and Bela-Bela;

– Although the quality of the measurement parameters improved south of Bela-Bela, the measurement parameters indicate the signal to be more susceptible to interference from external elements (marker F in Figure 28), compared to the 16QAM modulated signal (marked A, B and C in Figure 28);

– The effective coverage area will therefore reduce significantly when configured on a higher modulation scheme (64QAM) compared to a lower modulation scheme (16QAM).

FIGURE 29

**Route from transmitter to Polokwane (16QAM) – KinStar Antenna**




Studying Figure 29 (16QAM) the measurement parameters indicate the following:

– Passing under a bridge resulted in a short decrease in the S/N marked A in Figure 29 at a location of ±28 km from the transmitter station;

· The signal level S/N (red graphical line) and audio quality (purple graphical line) indicate a decrease for a short distance at the tollgate located at ±37 km and ±168 km from the transmitter station (marked B in Figure 29);

– The signal level S/N (red graphical line) and audio quality (purple graphical line) indicate a decrease for a short distance, passing under bridges located at a distance of ± 76 km, ± 83 km and ± 133 km from the transmitter station (marked C in Figure 29);

– The field strength (blue graphical line) as well as the S/N (red graphical line) indicates a significant decrease at a distance of ± 90 km from the transmitter station (marked D in Figure 29);

– As the northern part of the route approached a mountainous terrain it resulted in a decrease field strength, decrease in S/N, increase in BER and degradation of audio quality (marked E in Figure 29). Degradation of the signal in the mountainous terrain was due to various factors which included signal propagation path obstructions (due to the terrain) and also changes in the ground-conductivity which could clearly be noticed when correlating with the planning tool;

– The S/N, bit error ratio and the audio quality in the area just north of Bela-Bela (marked E in Figure 29) were found to be better than the Broadcom antenna (marked D in Figure 27);

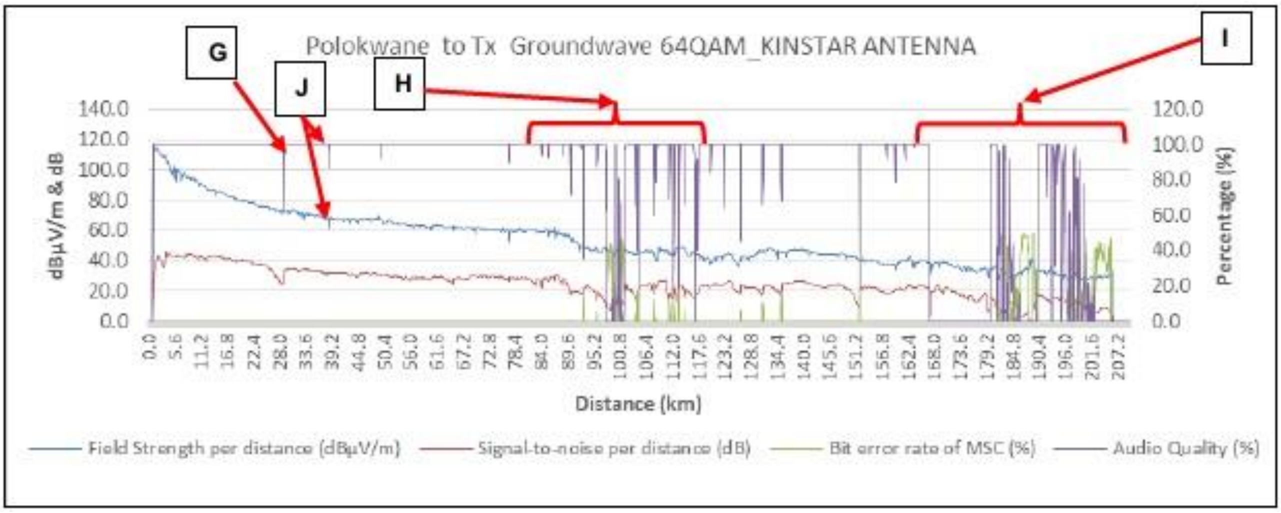
– The field strength and the S/N values continued to degrease as the distance from the transmitter increased;

– The field strength and S/N improve when exiting the mountainous terrain which resulted in the reduction of BER and improvement of audio quality. The overall quality of the signal was good and stable till another mountainous terrain was approached and entered.

– The field strength, S/N and audio quality decrease while the BER increase (marked F in Figure 29) due to the mountainous terrain at a distance of ±180 km from the transmitter station. This was as a result of a combination of factors which included the distance from the transmitter, change in ground-conductivity and propagation path obstruction by the mountainous terrain. The quality of the signal kept on changing till complete signal failure occurred a few kilometres before the Polokwane town, located at a distance ±200 km from the transmitter. On this radial route (Figure 29) the degradation on the audio was found to be less severe when compared to the Broadcom antenna measurement exercise on the same radial route (Figure 27).

FIGURE 30

**Route from Polokwane to transmitter (64QAM) – KinStar Antenna**




Studying Figure 30 (64QAM) the measurement parameters indicate the following:

– Once the route measurement from Pretoria to Polokwane was completed, the modulation was changed from the rugged 16QAM modulation setting, to the less-rugged 64QAM modulation setting. Measurements were then conducted in an opposite direction on the route from Polokwane to the transmitter station located in Pretoria;

– Increase in distance from the transmitter station resulted in decrease in field strength level, decrease in S/N, increase in BER and degradation of audio quality (marked I in Figure 30);

– The route from the north approached a mountainous terrain (Indicated with label H in Figure 30) which resulted in a decrease in the field strength, decrease in S/N, increase in BER and degradation of audio quality. Degradation of the signal in the mountainous terrain was due to various factors which included signal propagation path obstructions due to the terrain and also changes in the ground-conductivity, which could clearly be noticed, when comparing the measurement result locations with the planning tool;

– Although the signal level and the BER remained unchanged, the S/N and audio quality (red and purple graphical lines) decreased (marked G in Figure 30). The decrease in the S/N was caused by passing under a bridge at a distance of ±28 km from the transmitter station;

– Measurement results indicate a slight decrease in signal level and audio quality (Blue and purple graphical lines) for a short period of time at the tollgate located ± 37 km from the transmitter station (marked J in Figure 30);

– All measurement parameters improved as the distance from transmitter station decreased (driving back from Polokwane towards Pretoria).

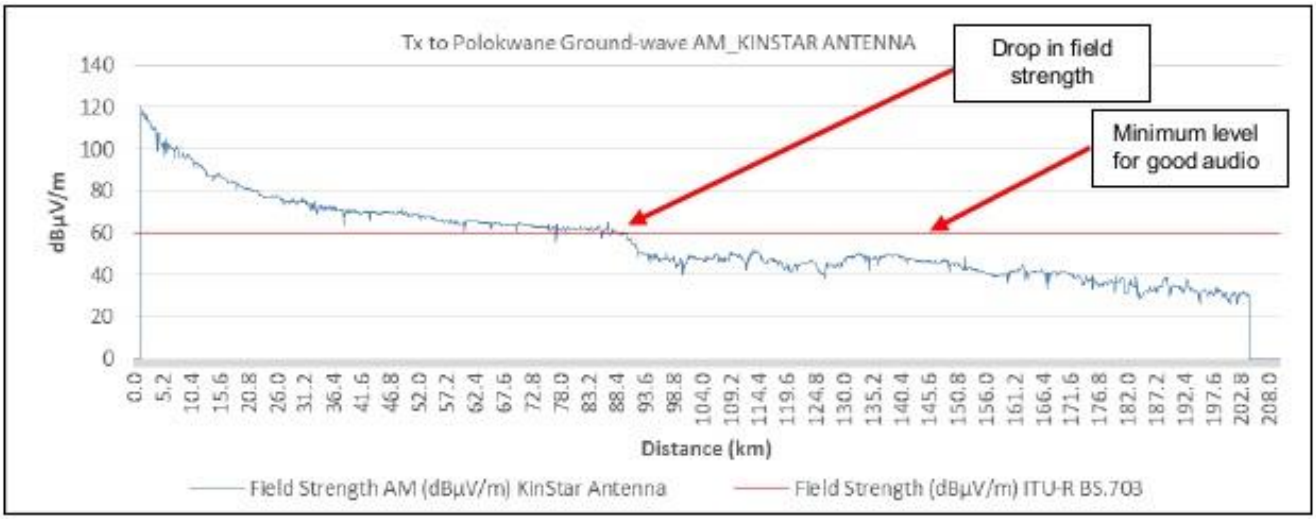
Comparison between the 16QAM and 64QAM KinStar antenna measurement results indicated the following:

– Comparisons between the measurement results in Figures 29 and 30 indicate the field strength to be more-or less similar on both graphs but with a significant decrease in S/N, increase in BER and the degradation of the audio quality, especially in the area marked by “H” on Figure 30. The less rugged modulation setting resulted in a severe degradation of the signal on the route located between ±166 km to 207 km from the transmitter station. Recovery of a stable signal was only detected ±97 km from the transmitter station. The combination of a less-rugged modulation setting, mountainous terrain and less ground-conductivity resulted in signal failure between Polokwane and Bela-Bela;

– Although the quality of the measurement parameters improved south of Bela-Bela, the measurement parameters indicate the signal to be more susceptible to interference from external elements (marked G and J in Figure 30), compared to the 16QAM modulated signal (Figure 29).

FIGURE 31

**Route from transmitter to Polokwane (AM Analogue) – KinStar Antenna**




Studying Figure 31 the analogue field strength measurement parameters indicate the following:

– Only the field strength parameter was measured on the AM analogue signal as indicated in Figure 31 above;

– The analogue field strength was found to follow the same trend as the measured DRM30 field strength levels;

– The field strength in Figure 31 indicates a reduction below the required level of 60 dBµV/m after a distance of ±90 km from the transmitter station. This is the minimum required field strength to ensure a good quality analogue medium wave signal according to the Recommendation ITU-R BS.703;

– Degradation of the signal was mainly experienced due to the mountainous terrain and less ground-conductivity (between Bela-Bela and Polokwane) in the area;

Comparison between the 16QAM, 64QAM and analogue AM on the KinStar antenna measurement results indicated the following:

– The measured field strength (blue graphical line) level followed the same trend as the DRM30 measurement levels irrespective of the type of modulation scheme used;

– All three modulation schemes (16QAM, 64QAM and analogue AM) were affected by tollgates, bridges, high voltage overhead cables and whenever driving in mountainous terrain areas;

– All three modulation schemes (16QAM, 64QAM and analogue AM) indicated a decrease in field strength level at a distance of ±90 km from the transmitter station (behind a mountain);

– The field strength measurement pattern is more-or-less the same for Figures 29, 30 and 31 because the measurements were conducted on the same radial route (north radial route);

– AM signal measurements indicated degradation of AM audio quality in mountainous terrain areas where some of the DRM30measurements (16QAM and 64QAM) indicated a slight improvement in decode-ability and audio quality;

– According to Recommendation ITU-R BS.703, the minimum field strength of 60 dBµV/m is required for analogue commercial receivers to provide good audio quality;

– According to Recommendation ITU-R BS.1615-1, the minimum field strength required for good audio quality on 16QAM and 64QAM DRM30 modulated signals are 33.1 dBµV/m and 38.6 dBµV/m respectively. Field measurements however indicated that a good DRM30 audio quality (100%) was only achieved at a field strength level of 56.2 dBµV/m for a 16QAM signal and 57.5 dBµV/m for a 64QAM signal. Based on these measurement findings it would therefore be preferable to consider to include an additional margin of 23.1 dB and 18.9 dB respectively to the recommended ITU field strength values for 16QAM and 64QAM DRM30 modulated signals to compensate for potential decode-ability constrains of the DRM30 modulated signal. Including these additional margins would have a direct impact on the decodable DRM30 coverage area. Coverage predictions based on these additional margins are presented in Figure 95, under Appendix G, which provide an indication on how decode-ability constrains of the DRM30 signal could impact the predicted coverage area which are based on the ITU recommended field strengths;

– DRM30 measurements on the more-rugged 16QAM modulation signal indicated that a decodable signal was measured at an average omnidirectional distance of 78 km from the transmitter station. The less-rugged 64QAM modulation signal indicated that a decodable signal was measured at an average omnidirectional distance of 68 km from the transmitter station. Changing the modulation from a less-rugged modulation scheme (64QAM) to a more-rugged modulation scheme (16QAM) indicate that the average coverage distance from the transmitter could be improved which would result in larger area coverage;

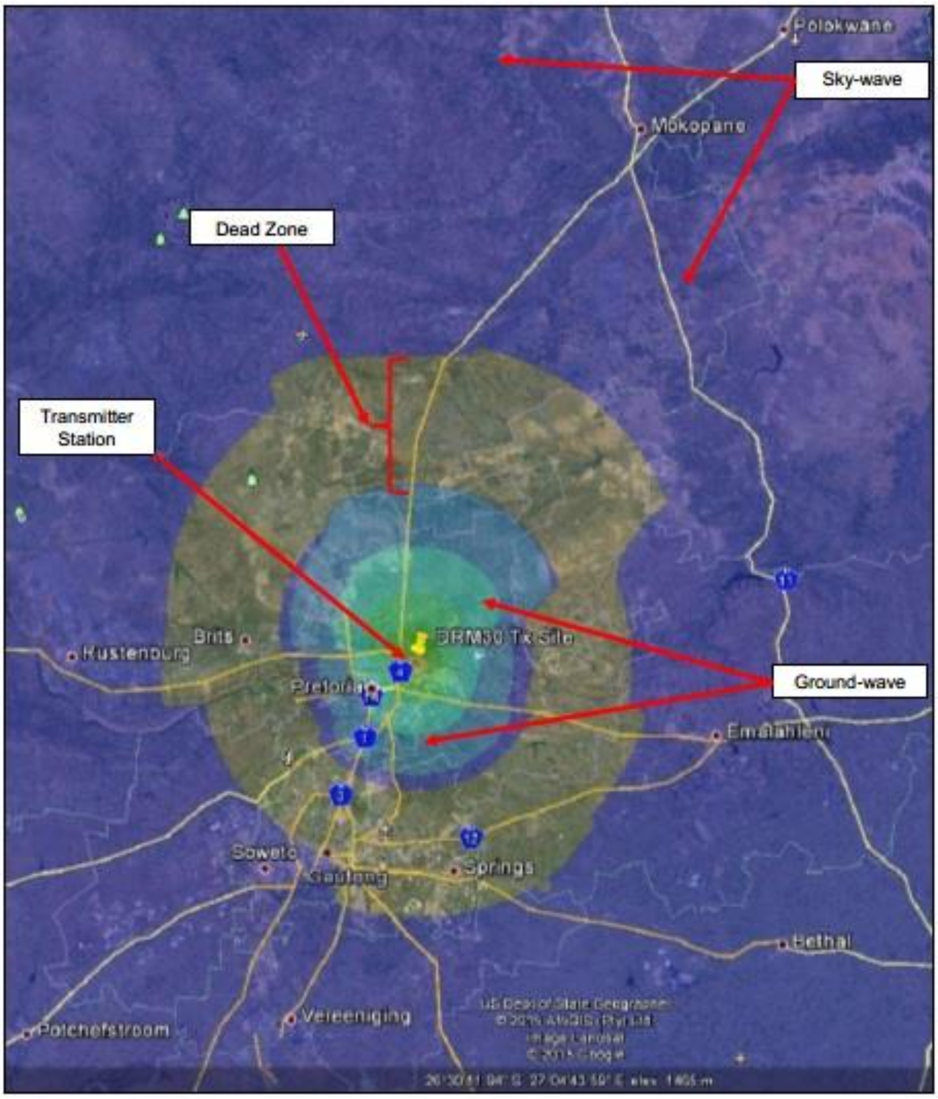
– The ground-wave signal is affected by various ground conditions which include ground conductivity, terrain roughness and dielectric constant. The planning tool includes a ground conductivity layer to assist in ground-wave predictions. According to the planning tool predictions there are different ground conductivity layers located in the areas where measurements where conducted. These different conductivity layers are presented in Figure 94, under Appendix F. Changes in signal strength measurements correlated with the predicted conductivity information which indicate that ground conductivity has a direct impact on the signal strength measurement values.

Notice should be taken that the sky-wave predictions on both antennas were conducted by using the antenna patterns of an isotropic antenna.

The sky-wave prediction is indicated in Figure 32 below. The ground-wave coverage area was predicted by using the propagation prediction model of Recommendation ITU-R P.1147. This prediction model excluded man-made noise such as bridges, high voltage overhead cables, tall buildings etc.

FIGURE 32

**Sky-wave predicted DRM30 coverage area**

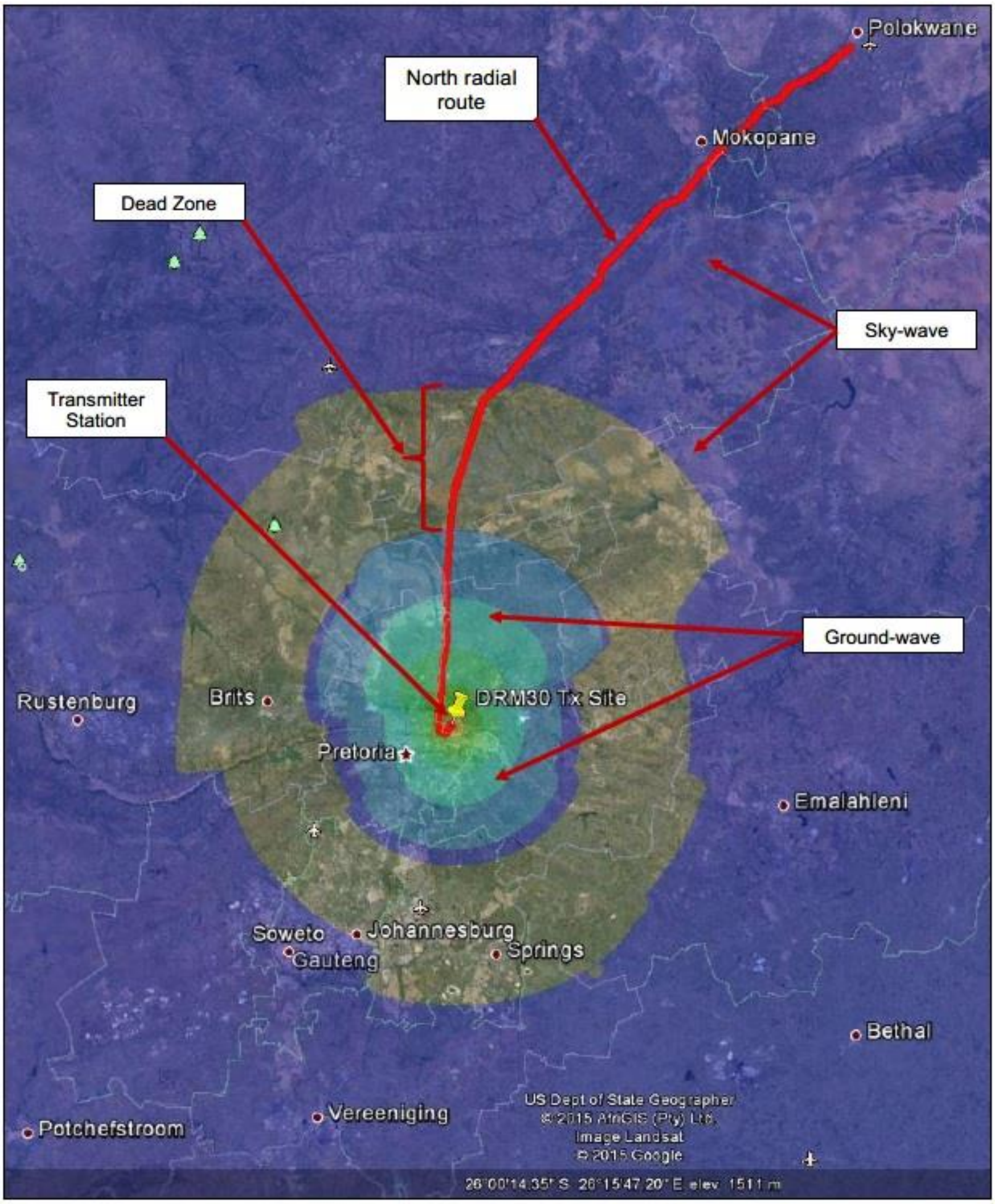


### 7.3.7 Sky-wave analysis

Sky-wave measurements were conducted by driving on the route indicated in Figure 33 below.

FIGURE 33

**Sky-wave measurement Drive-By measurement route.**




#### 7.3.7.1 Measurement correlations – sky-wave

Correlations between 74 550 measured and predicted field strength values for the Broadcom antenna are presented in Figure 34 which indicate the predicted field strength (green) and the measured field strength (yellow). On the route from the transmitter station to Polokwane the predicted dead-zone is also indicated in Figure 34. Studying the correlated measured field strength values indicated that the negative impact of the sky-wave is only experienced at a later stage (more distant) on the route than predicted. The negative impact of the sky-wave is indicated by the ripple on the correlated measured field strength values in Figure 34. Sky-wave dead-zone predictions conducted with the planning tool therefore differ considerably from the actual measured values as indicated in Figure 34.

FIGURE 34

**Sky-wave correlation for the Broadcom antenna (route from transmitter station to Polokwane and back)**

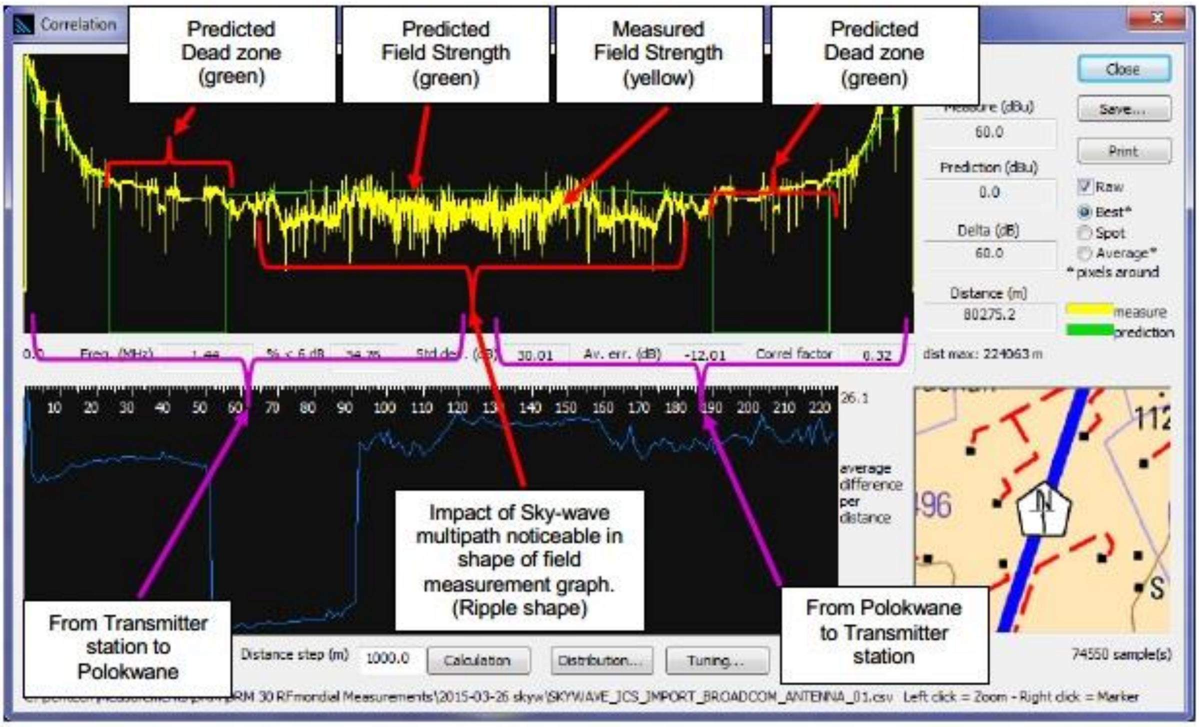
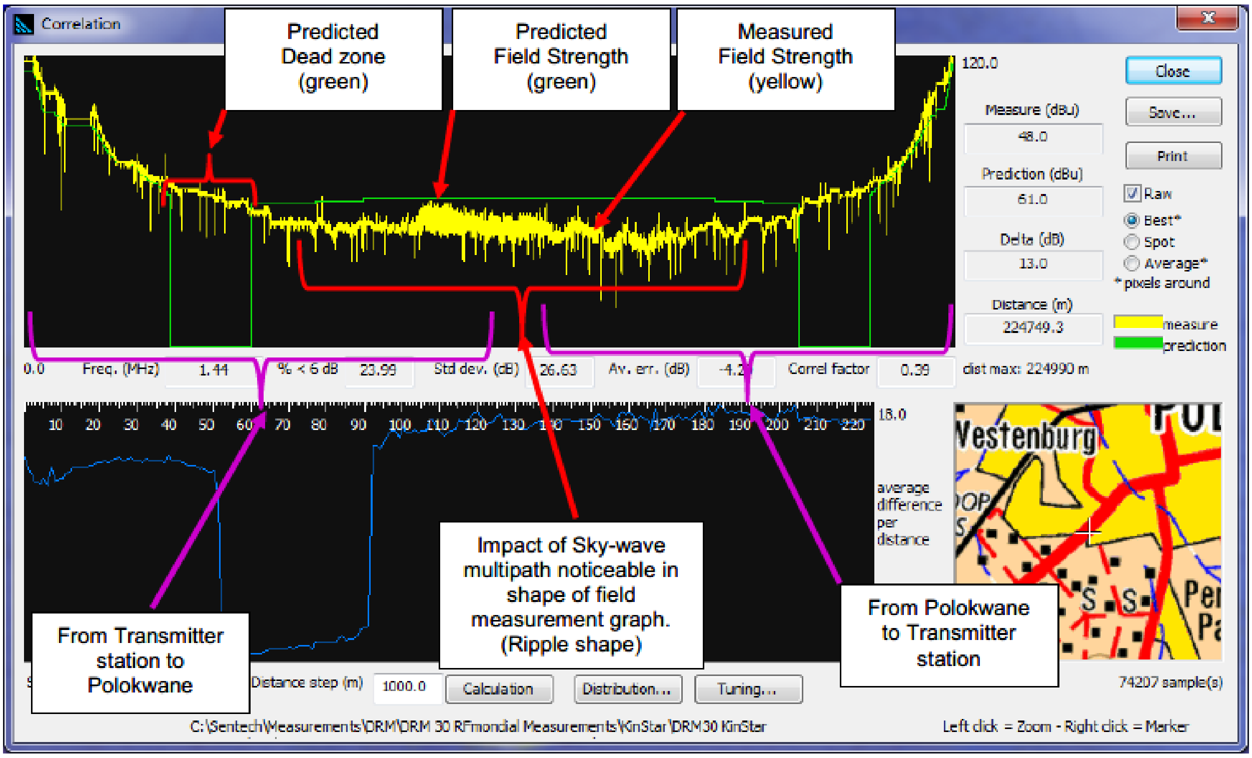


FIGURE 35

**Sky-wave correlation for the KinStar antenna (route from transmitter station to Polokwane and back)**




Comparison between the Broadcom antenna and the KinStar antenna sky-wave correlations indicate the following:

– Studying the "ripple effect" on the sky-wave multipath impact area between the two antennas clearly indicate more severe sky-wave multipath interference on the Broadcom antenna compared to the KinStar antenna.

Determining the impact of the sky-wave on the propagated ground-wave signal coverage area required measurements to be conducted during night-time (between sun-set and sun-rise). Measurements were conducted only on one radial route (north of the transmitter station), from the transmitter station to Polokwane with the Main Service Channel (MSC) on a 64QAM modulation setting, as well as from Polokwane to the transmitter station with the MSC on the lower and more rugged 16QAM modulation setting. The night-time measurements were conducted on both the Broadcom and KinStar antenna systems.

### 7.3.7.2.1. Sky-wave impact on Broadcom antenna

Figure 36 below provides details of the sky-wave measurements results on the Broadcom antenna with the MSC configured to a 16QAM modulation setting. The following measured parameters were analysed:

– Field Strength (dBµV/m) – indicated in blue;

– S/N (dB) – indicated in red;

– Bit Error Rate (%) – indicated in green;

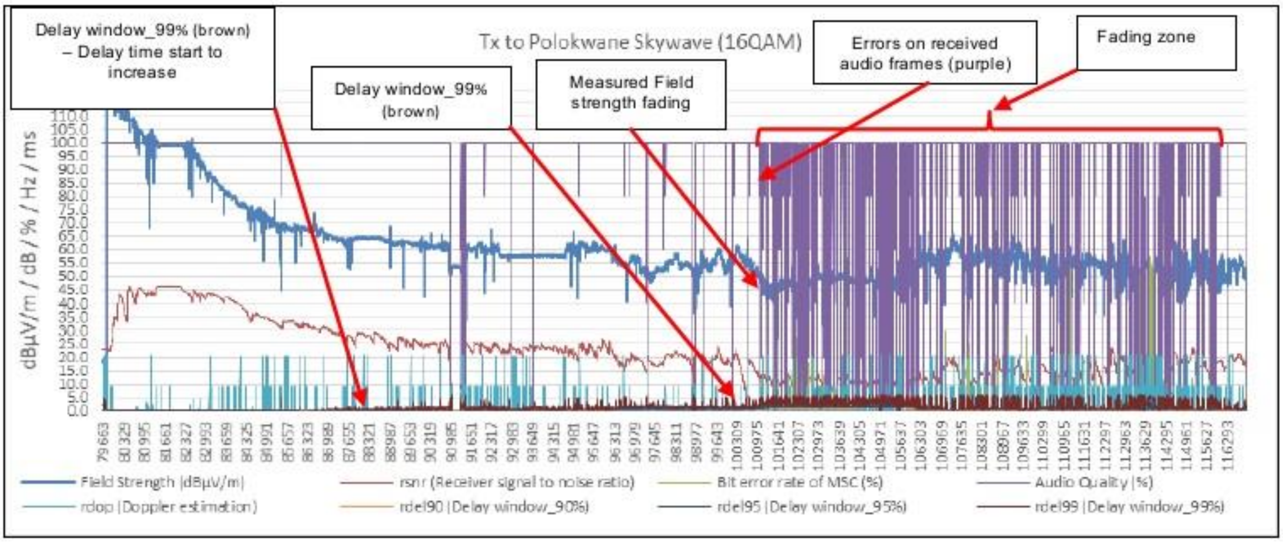
– Audio Quality (%) – indicated in purple;

– Doppler Estimation (Hz) – indicated in aqua;

– Delay Window (ms) – indicated in brown.

FIGURE 36

**Sky-wave measurements (16QAM modulation) Broadcom Antenna**




Studying the measured parameter values provide a clear indication of how the sky-wave impacted negatively on the ground-wave .The Delay window parameter trend line in Figure 36 provides a clear indication of the impulse response of the delayed sky-wave signal which started to interfere with the ground-wave. The Delay window measurement clearly indicate that a delayed signal was received (sky-wave) resulting in a delayed multipath effect starting at a location ±53 km north of the transmitter station. This correlated well with the predicted sky-wave fading zone, which predicted the severity of the sky-wave to start at a distance of ±55 km (Figures 32 and 33). Although the Delay window parameter and predicted starting point of the sky-wave was calculated and measured at a distance of ±53 km from the transmitter station, the degradation impact thereof on the ground-wave signal was only noted 47 km further north on this route, at a distance of ±100 km from the transmitter station. The impact of the sky-wave on the ground-wave increased slowly (increase in Delay window at 53 km from transmitter station) as the distance from the transmitter station increased. This resulted in a slow decrease of the S/N between the ground-wave and sky-wave till the point was reached where the sky-wave multipath caused the S/N to be too low to ensure good decode-ability (at a distance of ±100 km). At this point the Delay window, Doppler estimation, and BER increased rapidly resulting in a decrease in audio quality and which resulted in total audio failure.

Both the ground-wave and sky-wave signals were not decodable till ±116 km from the transmitter station. The sky-wave started to become the more dominant signal after ±116 km from the transmitter station. The sky-wave S/N, BER and audio quality improved, resulting in pure sky-wave reception from this point until the end of the measurement route with clear audio reception.

Studying Figure 36 as well as the impulse response measurement screen-shots (Figures 37, 38 and 39) the following could be noticed:

– Between Hammanskraal and Bela-Bela (±90 km from the transmitter station) the impulse response measurement (Figure 37) indicated that although multipath presence can be noted, the impact thereof on the ground-wave was not noticeable at all;

– Between Modimolle and Mokopane (±170 km from the transmitter station) the impulse response measurement (Figure 38) indicated that the impact of the increased sky-wave signal level, due to more constructive multipath (more sky-wave signals received in-phase) on the ground-wave, resulted in both the ground-wave and the sky-wave to be more or less at the same level, resulting in audio decode-ability failure as indicated in Figure 38;

– At a distance of 3 km before Polokwane (±220 km from the transmitter station) the sky-wave was the more dominant signal resulting in an improvement of the sky-wave clear signal level, sky-wave S/N, decrease of BER and increase of audio quality which enabled sky-wave reception as indicated in Figure 39. The impulse response measurement (Figure 39) indicates that the sky-wave was the most dominant signal at this point, which explains why sky-wave reception was possible at this point.

FIGURE 37

**Broadcom antenna. Impulse response indicating that the ground wave is dominant**


FIGURE 38

**Broadcom antenna. Impulse response indicating the fading zone**

FIGURE 39

**Broadcom antenna. Impulse response indicating that the sky wave is dominant**


### 7.3.7.2.2. Sky-wave impact on KinStar antenna

Figure 40 below provides details of the sky-wave measurements results on the KinStar antenna with the MSC configured to 16QAM modulation. The following measured parameters were analysed:

– Field Strength (dBµV/m) – indicated in blue;

– S/N (dB) – indicated in red;

– Bit Error Rate (%) – indicated in green;

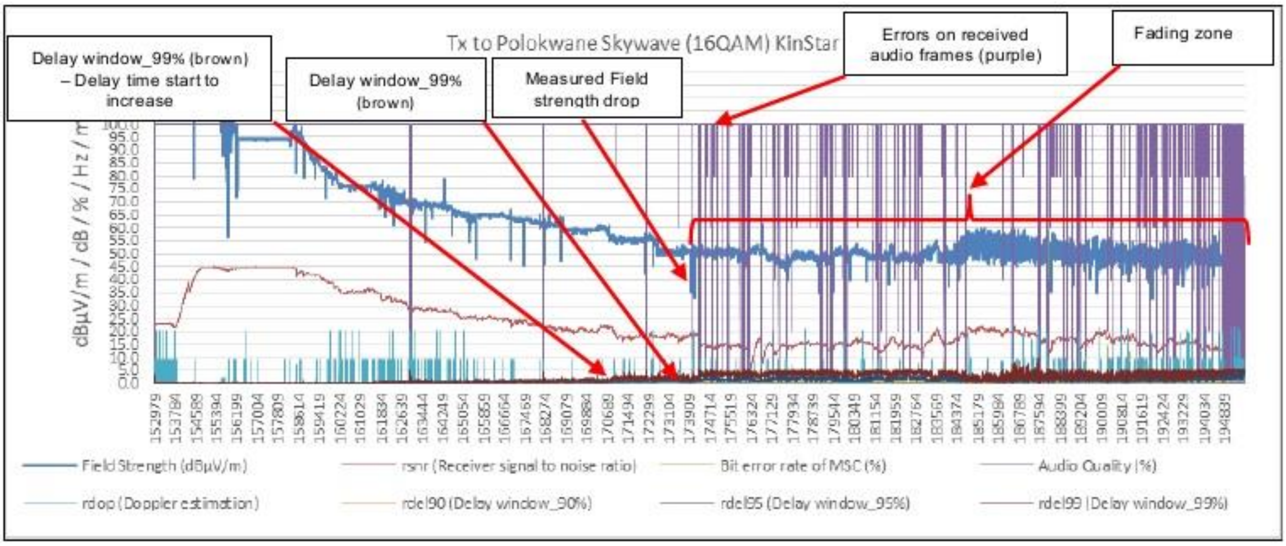
– Audio Quality (%) – indicated in purple;

– Doppler Estimation (Hz) – indicated in aqua;

– Delay Window (ms) – indicated in brown.

FIGURE 40

**Sky-wave measurements (16QAM modulation) KinStar Antenna**



The measured parameter values in Figure 40 provide a clear indication of how the sky-wave impacted negatively on the ground-wave .The delay window parameter trend line on the Figure 40 provide a clear indication of the impulse response of the delayed sky-wave signal which increased slowly till it started to interfere with the ground-wave signal. The delay window measurement clearly indicates that a delayed signal was received (sky-wave) which resulted in a delayed multipath effect at a location ±90 km north of the transmitter station. This does not correlate well with the predicted sky-wave fading zone, which predicted the severity of the sky-wave to start at a distance of ±55 km (Figures 32 and 33). Although the delay window parameter of the sky-wave was measured at a distance of ±90 km from the transmitter, the negative impact thereof on the ground-wave signal was only noted 10 km further north on this route, at a distance of ±100 km from the transmitter station. The impact of the sky-wave on the ground-wave increased slowly (increase in delay window at ±90 km from transmitter) as the distance from the transmitter station increased. This resulted in a slow decrease of the S/N between the ground-wave and sky-wave, from a distance of ±100 km from the transmitter station. At this point the Delay Window, Doppler Estimation, and BER increased rapidly resulting in a decrease in audio quality which eventually resulted in intermittent audio failure. There was no dominant sky-wave signal from Polokwane onward as in the case of the Broadcom antenna measurements.

Studying Figure 40 as well as the impulse response measurement screen-shots (Figures 7, 8 and 9) on the KinStar antenna the following could be noticed:

– Between the transmitter station and Hammanskraal (±30 km from the transmitter station) the impulse response measurement (Figure 41) indicated that although multipath presence can be noted, the impact thereof on the ground-wave was not noticeable at all;

– Between Modimolle and Mookgopong (±104 km from the transmitter station) the impulse response measurement (Figure 42) indicated that the sky-wave signal level increased due to more constructive multipath (more sky-wave signals received in-phase);

– Figure 43 indicates the impulse response between Mookgopong and Polokwane where the sky-wave signal and the ground-wave signal maintain the same level, which resulted in audio drop-outs. The audio quality (purple) in Figure 40 indicates that there is no improvement on the audio quality between Mookgopong and Polokwane, on the contrary the audio quality decrease a few kilometres from Polokwane (±220 km from the transmitter station).

FIGURE 41

**KinStar Antenna. Impulse response indicating that the ground-wave is dominant**

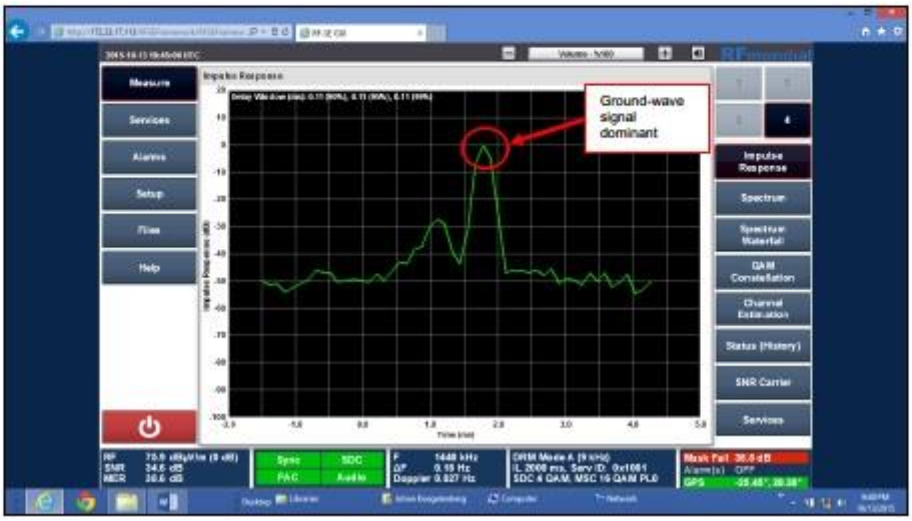
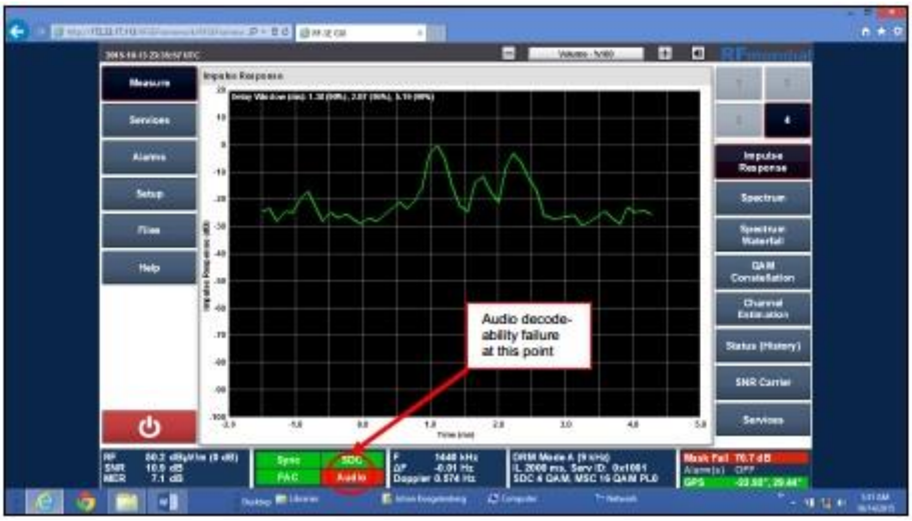



FIGURE 42

**KinStar Antenna. Impulse response indicating increase in sky-wave level.**

FIGURE 43

**KinStar Antenna. Impulse response indicating ground-and-sky-wave at the same level**




## 7.3.7.2.3 Sky-wave impact differences

FIGURE 44

**Broadcom antenna 16QAM Doppler estimation and Delay windows.**

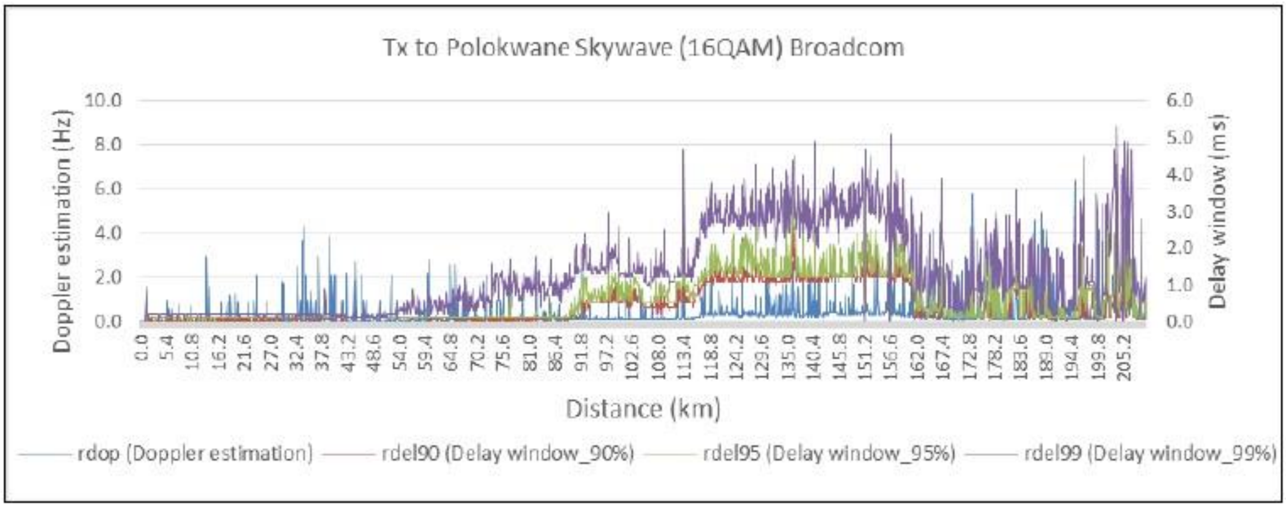


FIGURE 45

**KinStar antenna 16QAM Doppler estimation and Delay windows**

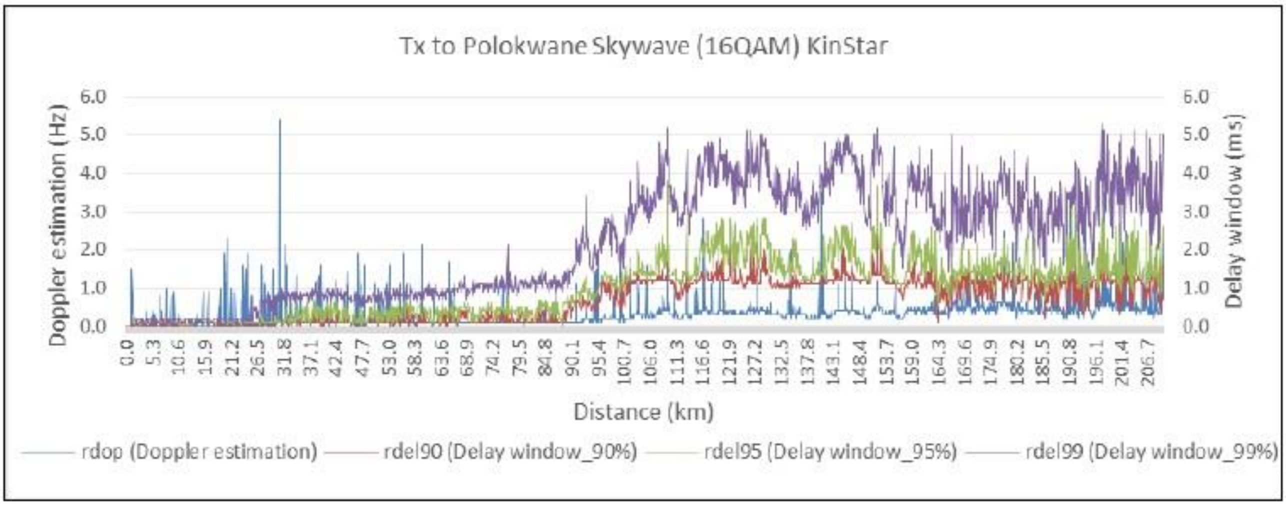



FIGURE 46

**Broadcom antenna 16QAM sky-wave measurements**

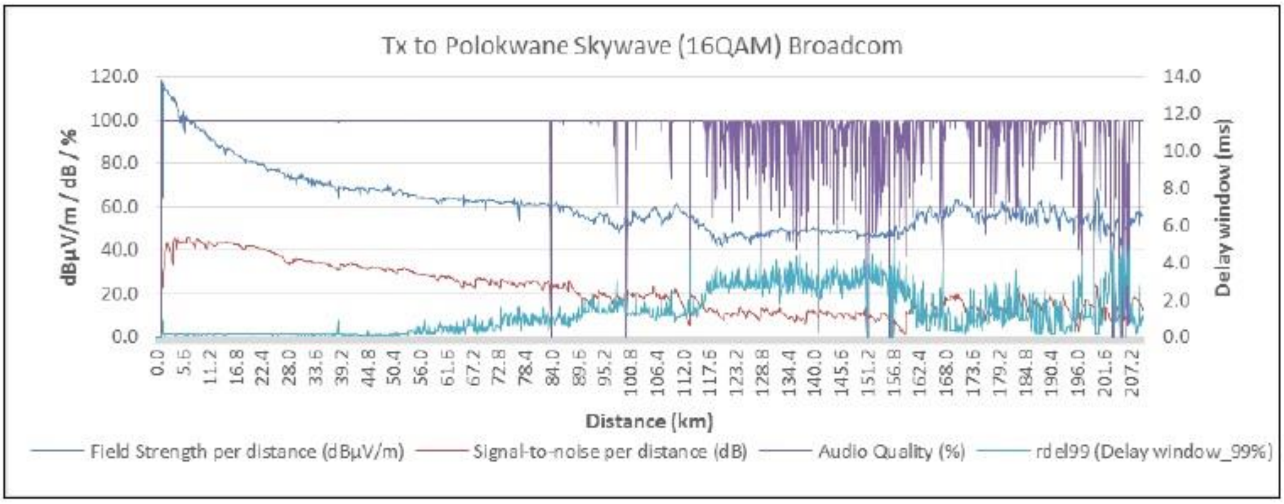
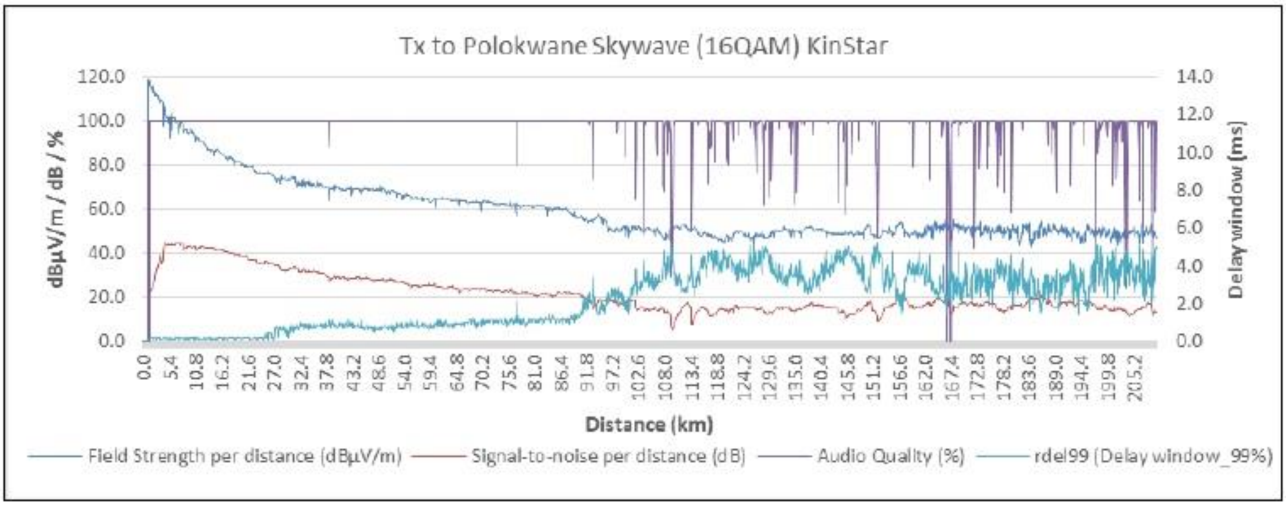


FIGURE 47

**KinStar antenna 16QAM sky-wave measurements**




The *Delay window* parameter (aqua graphical line) in Figures 46 and 47 indicated an increase of sky-wave presence at a distance of ±60 km from the transmitter station on the Broadcom antenna and at a distance of ±30 km on the KinStar antenna. There were no audio drop-outs on both antennas at this point because the ground-wave is still the dominant signal;

– At a distance between 114 km and 160 km from the transmitter station as indicated by the increase of the *Delay window* parameter level in Figure 46, the interference caused a decrease in field strength and S/N levels and severe audio drop-outs. Less interference were however experienced at a distance from 160 km onwards due to the sky-wave becoming the more dominant signal and the ground-wave insignificant as indicated by the decrease of the *Delay window* level, increase in field strength and S/N;

– The sky-wave was clearly noticed on the Broadcom antenna at a distance between 114 km and 160 km from the transmitter station as indicated by the increase of the Delay window parameter level in Figure 46, the interference caused a decrease in field strength and S/N levels and severe audio drop-outs. Less interference were however experienced at a distance from 160 km onwards due to the sky-wave becoming the more dominant signal and the ground-wave insignificant as indicated by the decrease of the Delay window level, increase in field strength and S/N;

– The sky-wave was clearly noticed on the KinStar antenna at a distance between 90 km and 210 km from the transmitter station, as indicated by the increase of the Delay window parameter level in Figure 47, the interference caused a decrease in field strength and S/N levels and audio drop-outs. Audio drop-outs remained constant until the measurements was stopped at a distance of 210 km; this indicated that no dominant sky-wave was present on the measurement route.

## 7.4 Signal performance findings

This section provides details on the overall performance of the transmitted signal for both the Broadcom and KinStar antennas.

### 7.4.1 Ground-wave signal performance findings

#### 7.4.1.1 16QAM modulated signal

Table 13 below indicates the average predicted and decodable coverage distances on the Broadcom and KinStar antennas.

TABLE 13

**16QAM Ground-wave predicted and measured decodable distances**

| Average coverage distance (16QAM) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Radial Direction | Broadcom Antenna | | | | KinStar Antenna | | | | Delta btw Broadcom Antenna and KinStar Antenna | |
| | Predicted Distance (km) | Actual Decoded Distance (km) | Difference between Predicted and Actual (km) | Difference between Predicted and Actual (%) | Predicted Distance (km) | Actual Decoded Distance (km) | Difference between Predicted and Actual (km) | Difference between Predicted and Actual (%) | Delta between Broadcom (+) and KinStar (-) (km) | Delta between Broadcom (+) and KinStar (-) (%) |
| | 16QAM | 16QAM | 16QAM | 16QAM | 16QAM | 16QAM | 16QAM | 16QAM | 16QAM | 16QAM |
| North | 134 | 94 | 40 | 30.1 | 134 | 100 | 33.8 | 25.2 | -6.5 | -6.5 |
| North-east | 126 | 87 | 39 | 31.3 | 126 | 80 | 46.3 | 36.7 | 6.9 | 8.0 |
| East | 118 | 55 | 63 | 53.6 | 118 | 48 | 69.9 | 59.2 | 6.6 | 12.1 |
| South-east | 177 | 98 | 79 | 44.4 | 177 | 91 | 85.6 | 48.4 | 7 | 7.1 |
| South | 177 | 64 | 113 | 63.7 | 177 | 71 | 105.8 | 59.8 | -7 | -9.8 |
| South-west | 143 | 110 | 33 | 23.4 | 143 | 99 | 43.7 | 30.6 | 10.3 | 9.4 |
| West | 123 | 52 | 71 | 57.6 | 123 | 62 | 61.1 | 49.7 | -9.8 | -15.8 |
| North-west | 183 | 82 | 101 | 55.1 | 183 | 68 | 114.8 | 62.7 | 14 | 17.0 |
| Average | 148 | 80 | 67 | 45 | 148 | 78 | 70 | 47 | 3 | 3 |

The following ground-wave signal performance findings could be concluded based on the results in Table 13:

– Measurements on both antennas indicate that the ground-wave signal does not propagate equally in all eight horizontal radial directions, therefore the distance of the decode-able signal will differ in each radial direction (refer to Table 13). The reason for the difference in service reception distance in the various radial directions depended on a variety of factors ranging from antenna propagation characteristics, ground conductivity, type of topographical terrain and man-made noise;

– Measurements on the Broadcom antenna with the more-rugged 16QAM modulated signal indicated that a decodable signal was measured at an average omnidirectional distance of 80 km from the transmitter station (refer to Table 13), ranging from 52 km till 110 km on the various radial measurement routes (refer to graphs 25 to 32 in Appendix B);

– Measurements on the KinStar antenna with the more-rugged 16QAM modulation signal indicate that a decodable signal was measured at an average omnidirectional distance of 78 km from the transmitter station (refer to Table 13), ranging from 48 km till 100 km on the various radial measurement routes (refer to graphs 41 to 48 in Appendix C);

– The average omnidirectional distance covered by the Broadcom antenna was 3 km further than the average omnidirectional distance of the KinStar antenna. This indicated that the Broadcom antenna was able to provide ±3% further coverage on the measurement route than the KinStar antenna when comparing the average omnidirectional distance of the 8 radial routes;

– The audio quality of the received signal on 16QAM from both antennas was not good (due to low modulation). The signal was however less susceptible to the negative impact of the type of topographical terrain, ground-conductivity, atmospheric conditions, man-made noise etc.

### 7.4.1.2 64QAM modulated signal

Table 14 below indicates the average predicted and decodable coverage distances on the Broadcom and KinStar antennas.

TABLE 14

**64QAM Ground-wave predicted and measured decodable distances**

| Average coverage distance 64QAM) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Radial Direction | Broadcom Antenna | | | | KinStar Antenna | | | | Delta btw Broadcom Antenna and KinStar Antenna | |
| | Predicted Distance (km) | Actual Decoded Distance (km) | Difference between Predicted and Actual (km) | Difference between Predicted and Actual (%) | Predicted Distance (km) | Actual Decoded Distance (km) | Difference between Predicted and Actual (km) | Difference between Predicted and Actual (%) | Delta between Broadcom (+) and KinStar (-) (km) | Delta between Broadcom (+) and KinStar (-) (%) |
| | 64QAM | 64QAM | 64QAM | 64QAM | 64QAM | 64QAM | 64QAM | 64QAM | 64QAM | 64QAM |
| North | 112 | 75 | 37 | 32.9 | 112 | 94 | 18 | 16.4 | -18.4 | -19.7 |
| North-east | 126 | 78 | 48 | 38.3 | 126 | 77 | 49 | 39.0 | 0.9 | 1.2 |
| East | 93 | 37 | 56 | 60.2 | 93 | 63 | 30 | 32.6 | -25.7 | -41.0 |
| South-east | 137 | 79 | 58 | 42.4 | 137 | * | * | * | * | * |
| South | 134 | 26 | 108 | 80.7 | 134 | 70 | 64 | 48.0 | -43.9 | -63.0 |
| South-west | 104 | 81 | 23 | 22.0 | 104 | 60 | 44 | 42.1 | 20.9 | 25.8 |
| West | 107 | 35 | 72 | 67.6 | 107 | 46 | 61 | 56.6 | -11.7 | -25.2 |
| North-west | 134 | 68 | 67 | 49.6 | 134 | 69 | 65 | 48.2 | -1.9 | -2.7 |
| Average | 116 | 57 | 59 | 50 | 116 | 68 | 47 | 40 | -11 | -18 |

* Due to a temporary error in the RFmondial RF-SE12, the devise was unable to measure the *rafs (audio status)* TAG which is used to calculate decoded distance (see Figure 82).

The following ground-wave signal performance findings could be concluded based on the results in Table 14:

– measurements on both antennas indicate that the ground-wave signal does not propagate equally in all eight horizontal radial directions, therefore the distance of the decode-able signal will differ in each radial direction (refer to Table 14). The reason for the difference in service reception in the various directions depend on a variety of factors ranging from antenna propagation characteristics, ground conductivity, type of topographical terrain and man-made noise;

– measurements on the Broadcom antenna with the less-rugged 64QAM modulated signal indicated that a decodable signal was measured at an average omnidirectional distance of 60 km from the transmitter station (refer to Table 14), ranging from 26 km till 81 km on the various radial measurement routes (see Figures 64 to 71 in Appendix B);

– measurements on the KinStar antenna with the less-rugged 64QAM modulation signal indicated that a decodable signal was measured at an average omnidirectional distance of 68 km from the transmitter station (refer to Table 14), ranging from 46 km till 94 km on the various radial measurement routes (see Figures 80 to 87 in Appendix C);

– the average omnidirectional distance of the KinStar antenna was 11 km further than the average omnidirectional distance of the Broadcom antenna. This indicated that the KinStar provide ±18% improvement in average coverage distance compared to the Broadcom antenna;

– although the audio quality of the received signal on 64QAM for both antennas was good, it was more susceptible to the negative impact of the type of topographical terrain, ground-conductivity, atmospheric conditions, man-made noise due to the higher modulation setting.

The type of modulation setting (16QAM vs 64QAM) had a major impact on the decode-ability of the signal, which had a direct impact on the coverage area in which the receivers were able to decode the signal. Changing the modulation from a higher modulation (64QAM) to a lower modulation (16QAM) the average coverage distance (from the transmitter) could be improved. The negative aspect of configuring to the low, more robust 16QAM configuration is that the audio quality is not as good as the 64QAM modulated signal. Another negative aspect was that only one audio service could be carried by the 16QAM modulation setting in comparison to the two services on the 64QAM modulation setting.

The type of antenna (Broadcom vs KinStar) had an impact on the average omnidirectional distance in which the DRM30 signal was decodable. The Broadcom antenna had a 3 km further average omnidirectional distance than the KinStar antenna on the 16QAM modulation scheme. The KinStar antenna had an 11 km further average omnidirectional distance than the Broadcom antenna on the 64QAM modulation scheme.

### 7.4.2 Sky-wave signal performance findings

The following sky-wave signal performance findings could be made based on the measurement analysis:

– Measurement results on both antennas indicated that the interference from the sky-wave did not negatively impact the DRM30 ground-wave coverage area during the night;

– Measurements on the Broadcom antenna indicated that the sky-wave became the more dominant carrier at a distance of ±116 km from the transmitter station;

– Measurements results indicated that the KinStar antenna had less sky-wave interference on the ground-wave compared to Broadcom antenna and that the sky-wave propagation was almost non-existent beyond the ground-wave coverage area on the KinStar antenna.

### 7.4.3 Factors impacting negatively on signal performance

Several factors have been identified to have negative impact on the performance of the signal with regard to signal reception which includes the following:

– Passing through toll-gates impacted negatively on both the received field strength and the S/N levels which reduced and recovered rapidly whenever the measurement vehicle passed through tollgates. This resulted in an increase of BER and the reduction of audio quality for a short time period (indicated in Figure 48);

– Driving underneath high voltage overhead cables also caused the received field strength and the S/N levels to reduce and recover rapidly which also resulted in an increase of BER and reduction of audio quality for a short time period (indicated in Figure 49);

– Mountainous terrains impacted negatively on S/N, BER and Audio Quality. Poor ground conductivity in mountainous terrains seem to have a negative impact on signal propagation (refer to measurement analysis Figure 50);

– Driving underneath bridges caused the received field strength and the S/N levels reduce rapidly which resulted in an increase of BER and reduction of audio quality (refer to measurement analysis Figure 51);

– Night-Time sky-wave interference (refers to measurement analysis Figure 36 and Figure 40);

– Antenna design has an enormous impact on signal performance. This was clearly noticeable when the Broadcom antenna measurement results were compared with the measurement results on the KinStar antenna. One of the most important aspects noticed was the importance of the antenna to produce a good broadband signal (good overall in band). Providing good transmit signal levels to most of the digital signal carriers were found to be essential. One of the other antenna requirement findings was that by providing an antenna with the capability to propagate more energy in the ground-wave resulted in an improved signal in the coverage area resulting in larger area coverage. The other positive aspect with regard to more concentrated energy in the direction of the ground-wave was that less energy is propagated skywards which means that there is less sky-wave interference impact on the ground-wave coverage during the night time.

FIGURE 48

**Tollgate impacting negatively on service and audio quality**

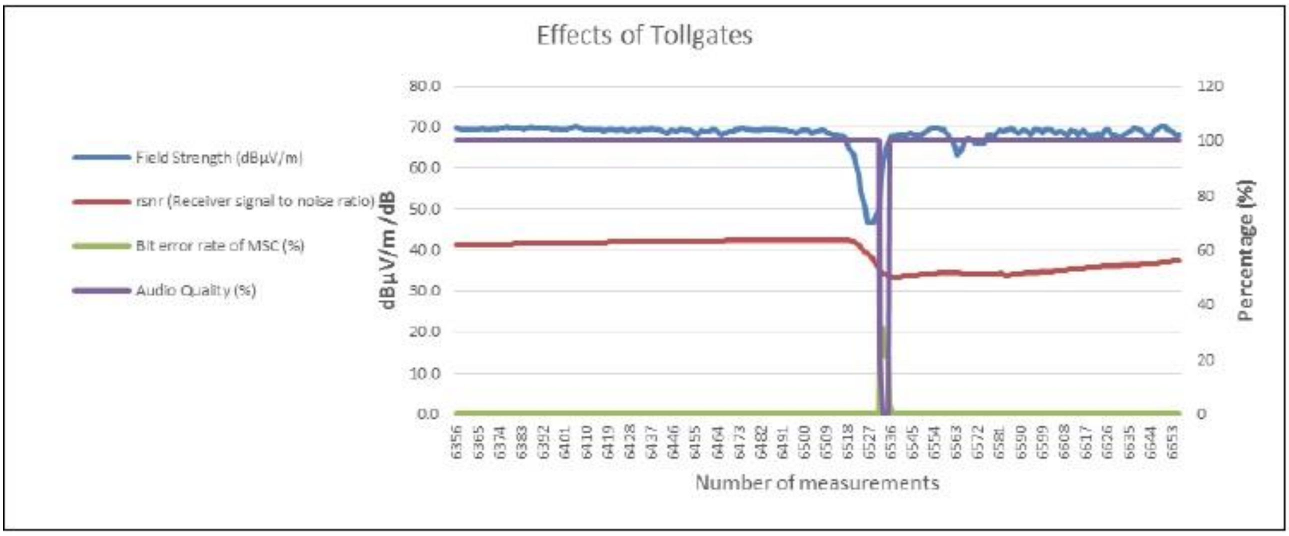


FIGURE 49

**High voltage overhead cables impacting negatively on service and audio quality**

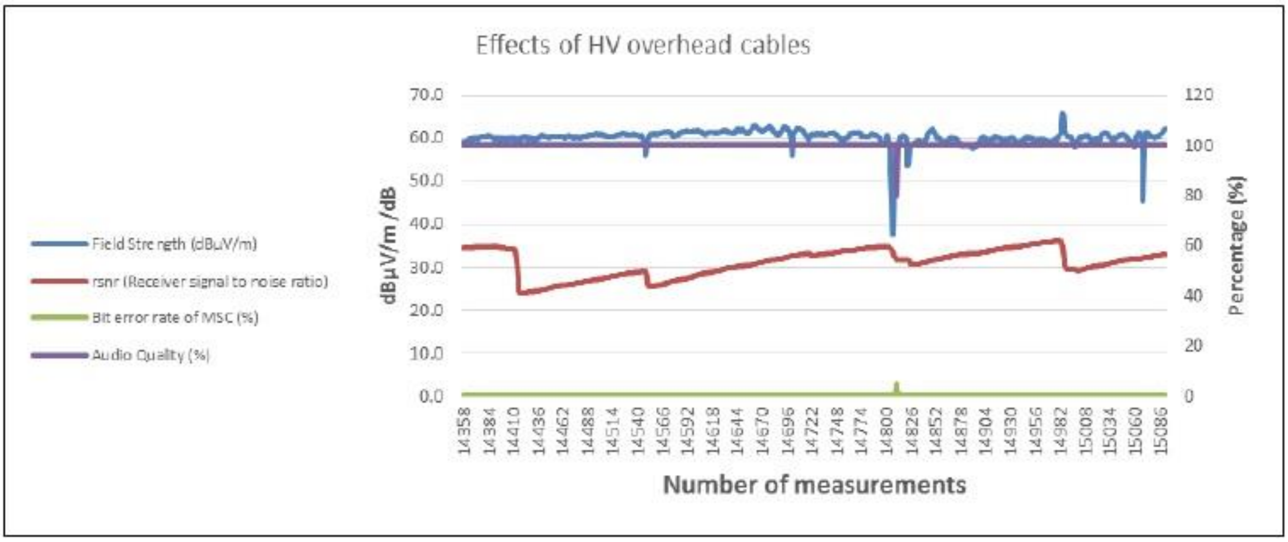



FIGURE 50

**Mountainous terrain impacting negatively on service and audio quality**

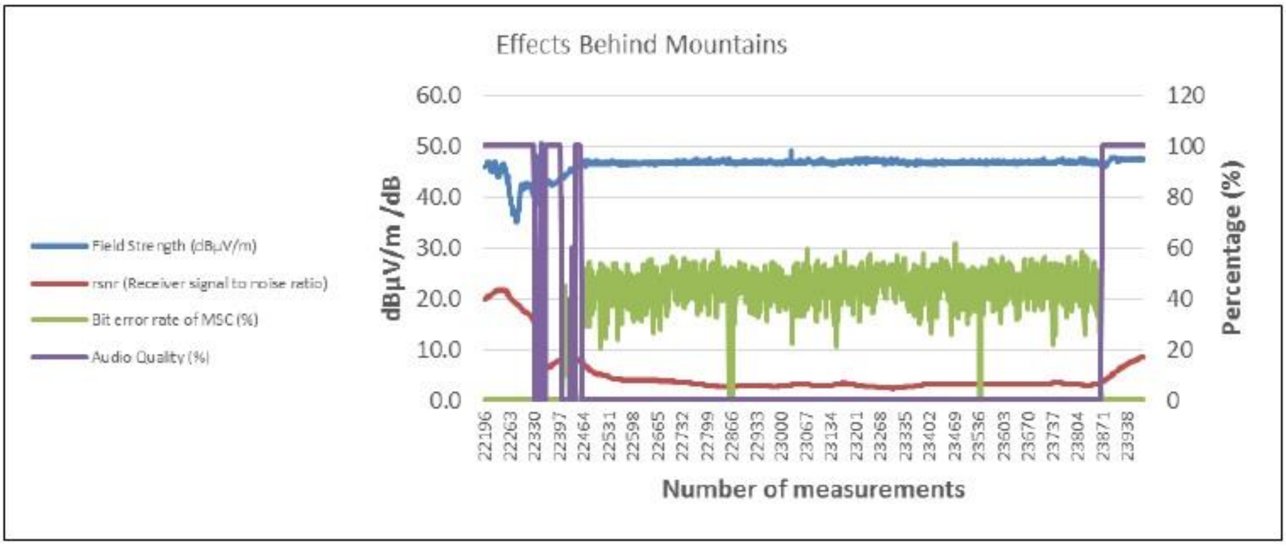
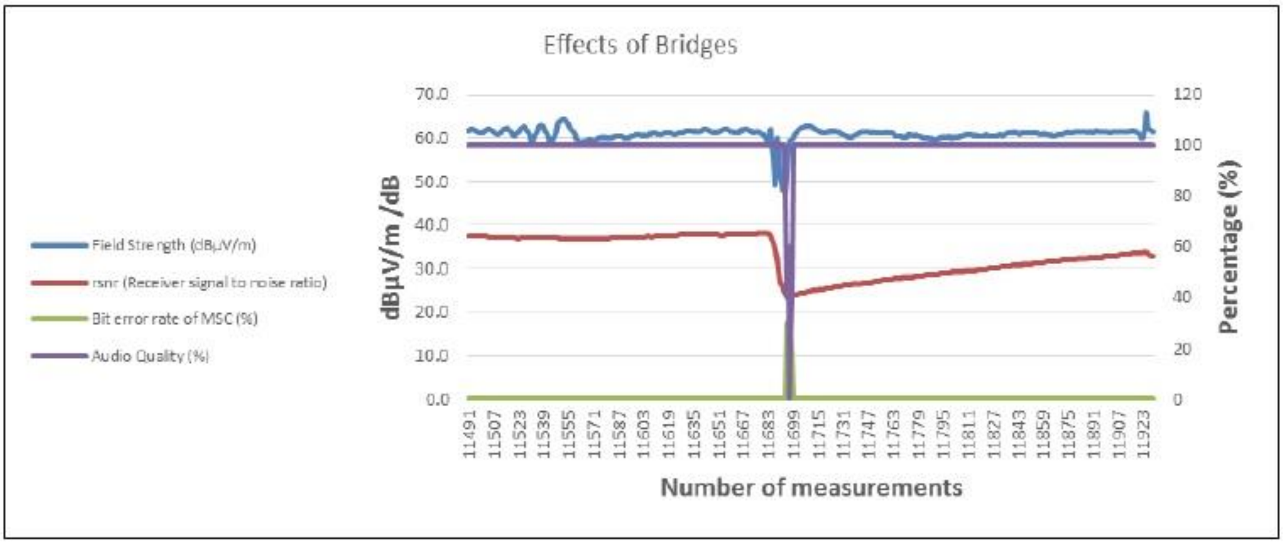


FIGURE51

**Driving underneath bridges impacting negatively on service and audio quality**




## 7.5 Performance of commercial receivers

The commercial receivers used to evaluate the DRM30 signal decode-ability and quality are shown in Table 15.

TABLE 15

**DRM30 commercial receivers used in DRM30 trial**

| Manufacturer | Model | Picture |
|---|---|---|
| Morphy Richards | 27024 |  |
| UniWave | Di-Wave 100 |  |

| Manufacturer | Model | Picture |
|---|---|---|
| Himalaya | DRM2009 |  |
| NewStar | DR-111 |  |

The performance of the commercial receivers was monitored at various static locations on the various radial routes. At each static measurement location each one of the receivers were tested to determine if the signal was decode-able and also to monitor the audio quality. Evaluation of the performance of the commercial receivers indicated that the overall performance of the various commercial receivers varied considerably with regard to their sensitivity and their ability to decode the received signal. The most sensitive commercial receiver was the Morphy Richards 27024, followed by the UniWave Di-Wave 100. The other two commercial receivers performed quite poor with regard to sensitivity and decodability.

Test-point (TP) locations where the commercial receivers were tested during the drive-by measurement exercises in the 16QAM and 64QAM coverage areas of the two types of antennas (Broadcom and KinStar) are indicated in Figures 52, 53, 54 and 55. Commercial receiver performance was also tested in the analogue (AM) coverage area at the locations indicated in Figure 56.

Results on the commercial receiver performance in the different signal coverage areas can be summarized as follow:

– In the Broadcom antenna 16QAM ground-wave coverage area a total number of 83 test points were recorded, out of which 36 test points (green pins on Figure 52 map 16) indicated the signal to be receivable and decode-able with good audio quality and 47 test points (red pins on map 16) were found to be non-decodable. Statistically 43% of the measured test points were decode-able in the Broadcom antenna 16QAM predicted ground-wave coverage area;

– A total number of 87 test points were recorded in the KinStar antenna 16QAM ground-wave coverage area, out of which 31 test points (green pins on Figure 53) indicated the signal to be receivable and decode-able with good audio quality and 56 test points (red pins on Figure 53) were found to be non-decodable. Statistically 36% of the measured test points were decode-able in the KinStar antenna 16QAM predicted ground-wave coverage;

– Out of a total number of 50 test points in the Broadcom antenna 64QAM ground-wave coverage area, 14 test points (green pins on Figure 54) indicated the signal to be receivable and decode-able with good audio quality and 36 test points (red pins on Figure 54) were found to be non-decode-able. Statistically 28% of the measured test points was decode-able in the Broadcom antenna 64QAM predicted ground-wave coverage area and 72% non-decode-able;

– In the KinStar antenna 64QAM ground-wave coverage area a total number of 57 test points were recorded, out of which 18 test points (green pins on Figure 55) indicated the signal to be receivable and decode-able with good audio quality and 39 test points (red pins on Figure 55) were found to be non-decodable. Statistically 32% of the measured test points were decode-able in the KinStar antenna 64QAM predicted ground-wave coverage area;

– A total of 14 test points in the KinStar antenna analogue AM ground-wave coverage area were recorded, out of which 4 test points (green pins on Figure 56) indicated the signal to be good and 10 test points (red pins on Figure 56) were found to be noisy and bad. Statistically 29% of the measured test points indicated a good audio quality in the analogue AM ground-wave coverage area.

FIGURE 52

**Commercial receiver test points in the predicted Broadcom antenna 16QAM ground-wave coverage**

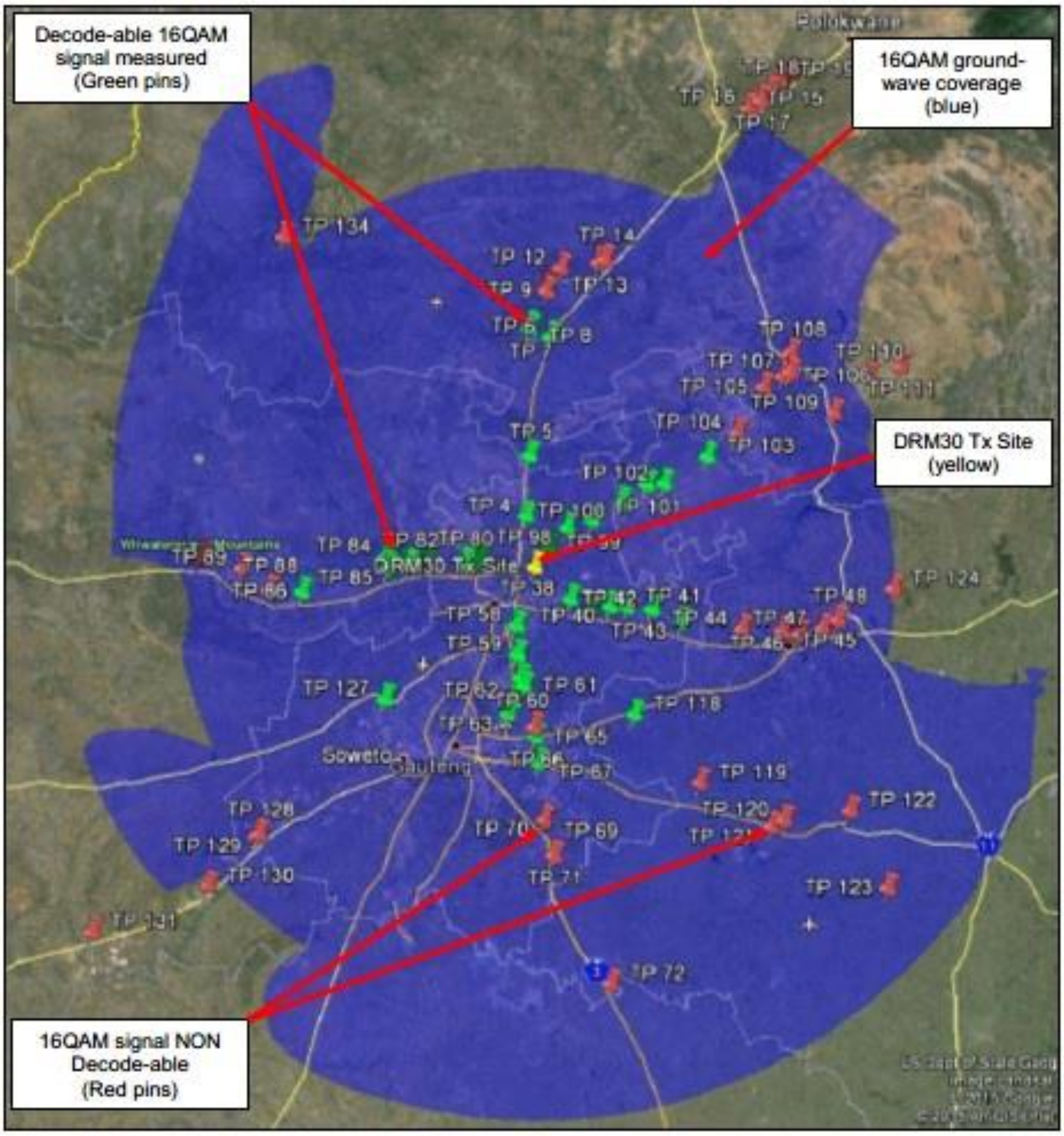


FIGURE 53

**Commercial receiver test points in the predicted KinStar antenna 16QAM ground-wave coverage**

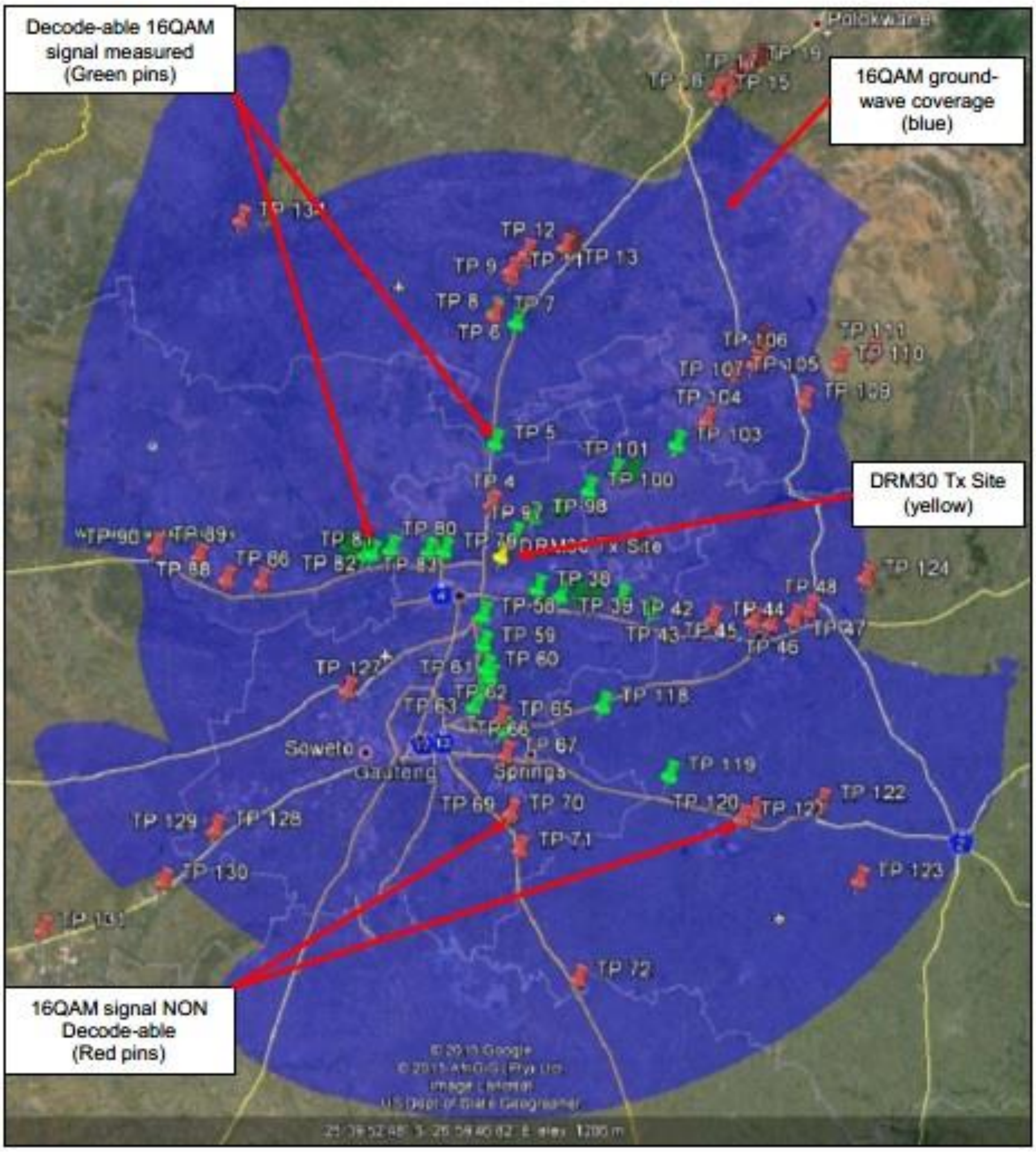


FIGURE 54

**Commercial receiver test points in the predicted Broadcom antenna 64QAM ground-wave coverage**

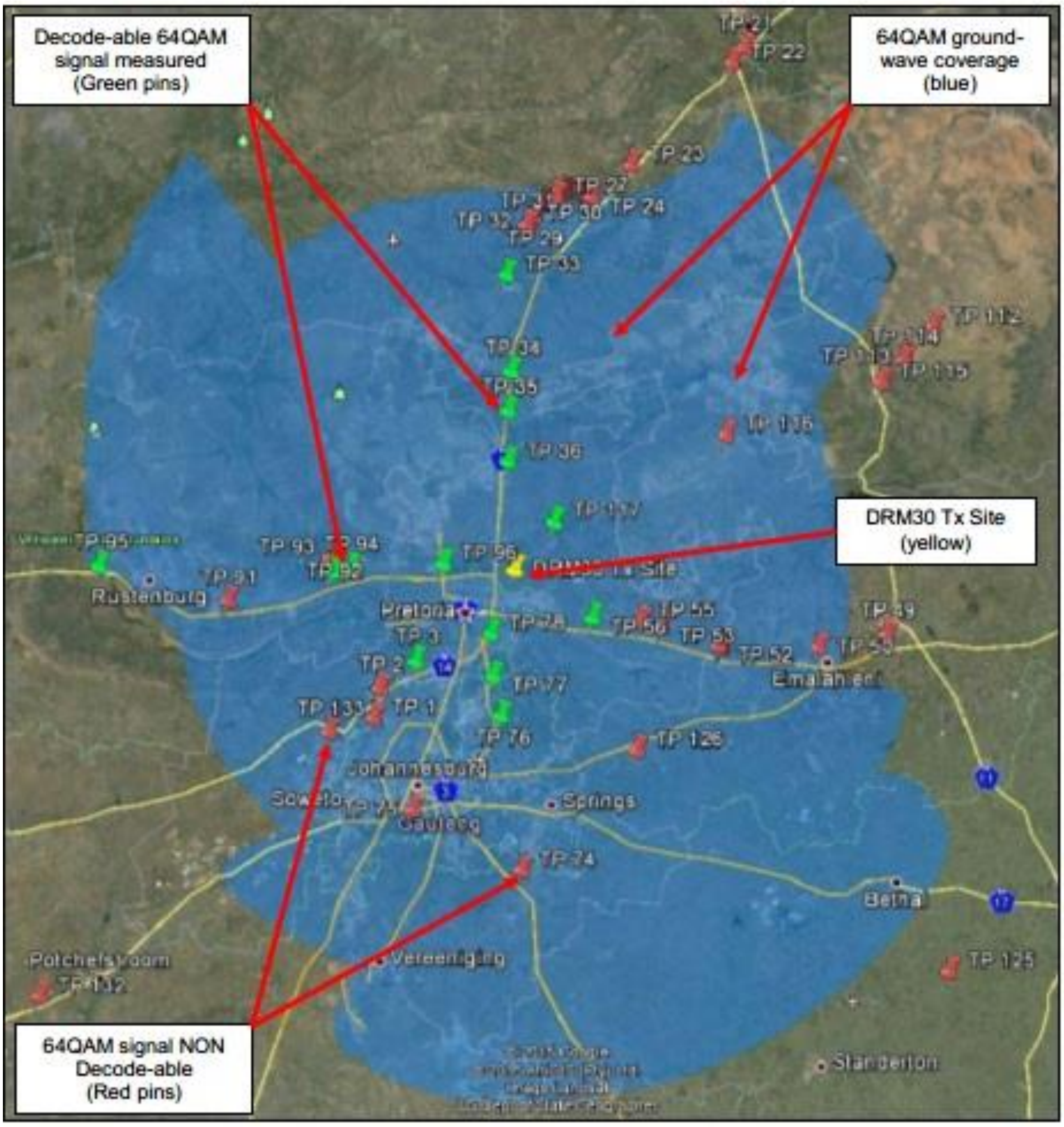


FIGURE 55

**Commercial receiver test points in the predicted KinStar antenna 64QAM ground-wave coverage**

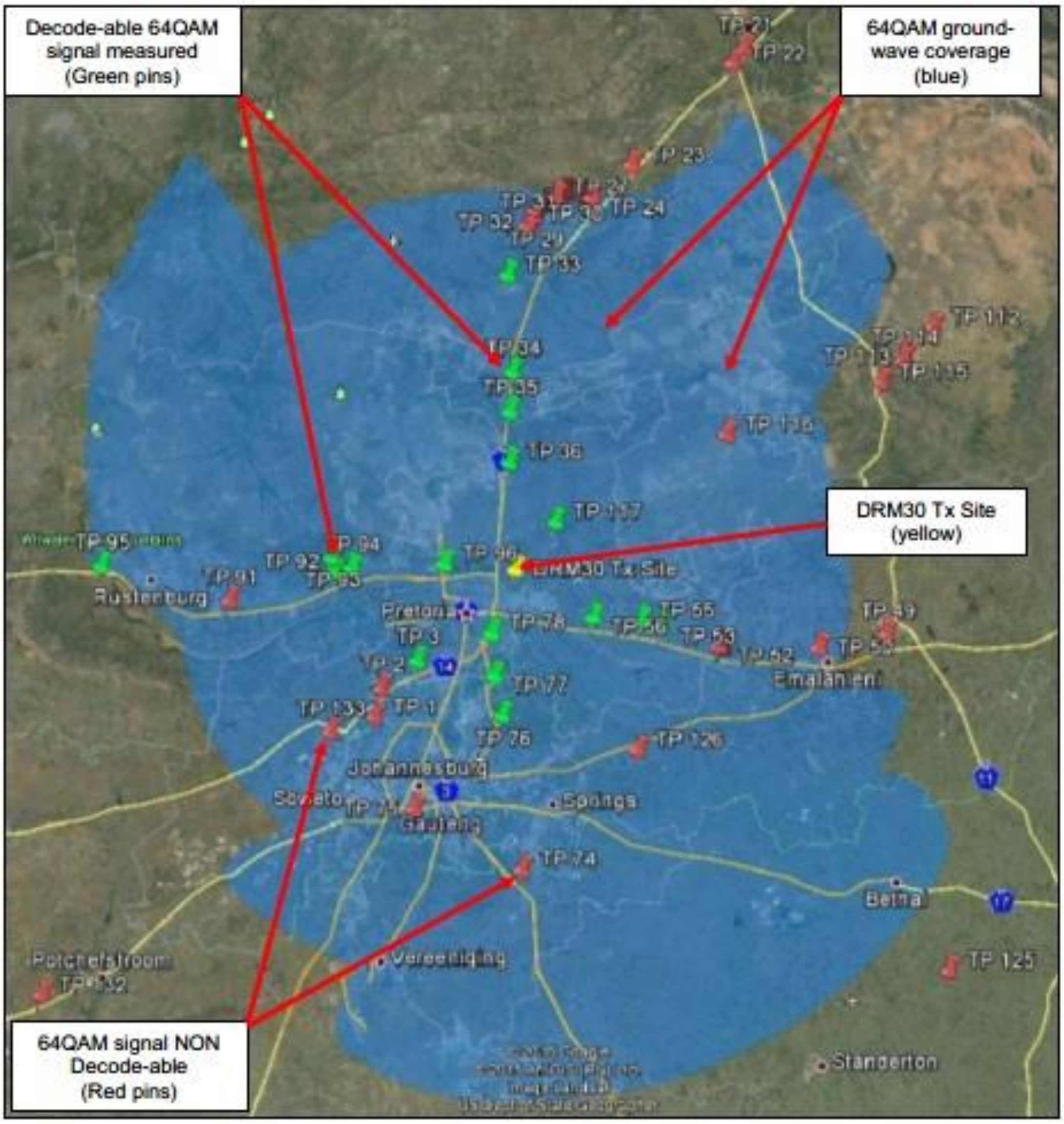
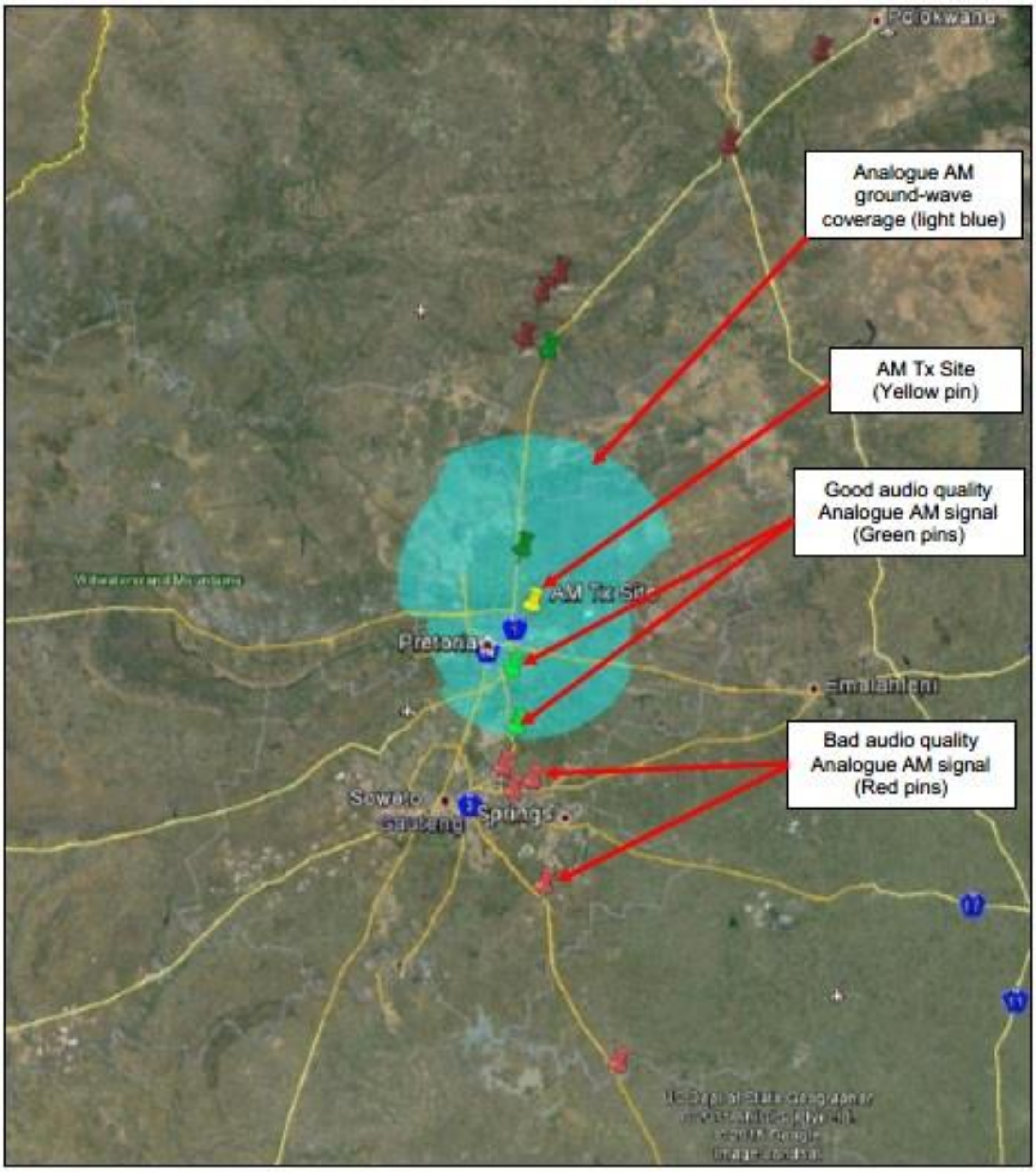


FIGURE 56

**Commercial receiver test points in the predicted KinStar antenna analogue AM ground-wave coverage**




## 8 Conclusions

Sufficient measurement data was obtained for analysis purposes which assisted in reaching a conclusion on the overall performance of the DRM30 technology. The following conclusions could be made based on the DRM30 trial:

– Both Low profile MW antennas (Broadcom and KinStar) were capable to provide good signal coverage;

– The KinStar antenna has a better VSWR over the 9 kHz bandwidth;

– Measurement tools were easily obtainable and the overall performance of the tools was found to be satisfactory;

– The measurement method selected by allocating routes per radial proved to be successful since it provided a good indication of the area coverage;

– Configuration of the DRM30 modulation (16QAM and 64QAM) during the measurement exercise provided sufficient information to determine the differences in performance between the two modulation schemes (16QAM and 64QAM);

– Both antenna system's (Broadcom and KinStar) measured horizontal radiation patterns indicated performance results which were better than predicted;

– Measurements with the analogue test signal (no modulation, narrow band signal) indicated that the Broadcom antenna have slightly higher gain than the KinStar antenna;

– Field strength correlation results between predicted and measured values indicate the predictions to be fairly accurate (50.9% of measured values within ±3dB on the Broadcom antenna and 95.9% of measured values within ±3dB on the KinStar antenna). Coverage predictions on the KinStar antenna were therefore found to be much more accurate;

– Field strength measurement results indicated that the propagated ground-wave does not radiate equally in all horizontal directions due to ground conductivity, nature of the topographical terrain, man-made noise etc.;

– Modulation configuration selection had a direct impact on signal coverage area and data throughput (data rate). The 16QAM modulation configuration setting provided a more robust signal resulting in a larger signal coverage area compared to the 64QAM modulated signal which provided a higher data rate and a smaller signal coverage area;

– DRM30 indicated improved spectrum usage in that DRM30 was capable of transmitting two audio services on the same AM frequency and bandwidth;

– Added to the audio service text messages and Journaline were also transmitted which was seen on the receiver end;

– The Broadcom antenna provided slightly better DRM30 ground-wave coverage than the KinStar antenna when the decode-ability of the 16QAM signal was compared. The Broadcom antenna has slightly higher gain than the KinStar antenna;

– The KinStar antenna provided slightly better DRM30 ground-wave coverage than the Broadcom antenna when the decode-ability of the 64QAM signal was compared. This was due to the better VSWR over the 9 kHz bandwidth on the KinStar antenna compared to the Broadcom antenna;

– The measured DRM30 signal performed better than the measured analogue AM signal with regard to area coverage;

– Both the DRM30 signal and analogue AM signal were susceptible to signal degradation caused by man-made noise (tollgates, bridges, high voltage overhead cables etc.);

– Sky-wave field strength measurements indicated that the Broadcom antenna had more interference caused by the sky-wave compared to the KinStar antenna. This was noticeable when measurement results indicated more sky-wave reflections caused by the Broadcom antenna compared to the KinStar antenna. The sky-wave interference occurred outside the daytime ground-wave coverage area which confirms that it should not have a negative impact on the daytime ground-wave coverage area;

– Services cannot be guaranteed in the sky-wave coverage areas;

- DRM30 measurement results indicated that all commercial receivers performed poorly with regard to signal reception when compared to the DRM30 measurement test results and the ITU recommendations;
- Performance between the different DRM30 commercial receiver manufacturer models differed quite significantly, indicating quite a vast difference with regard to sensitivity;
- The evaluated DRM30 commercial receivers were also found to be quite power intensive resulting in regular battery changes. This was also an indication of poor power efficiency which might be a problem in areas where no electricity is available;
- Availability of affordable and good quality DRM30 receivers as well as the limited number of manufacturers should be taken into consideration before selecting DRM30 as a broadcast medium;
- DRM30 broadcast can be considered as a greener technology due to 40% reduction in electricity consumption compared to the AM broadcast when covering the same area;
- DRM30 provides better audio quality and larger area coverage compared to analogue AM.

Due to time limitations not all tests were conducted, it is therefore recommended that the following could be conducted in future measurement trials:

- Antenna pattern measurements (Airborne measurements);
- Single frequency network (SFN) operation using the DRM30 system;
- Receiver evaluation;
- Emergency warning feature (EWF);
- Alternative frequency signalling (analogue AM, FM and DAB);
- Additional features (DRM Text messages and Journaline text information service).

## REFERENCES

1 ETSI ES 201 980, Digital Radio Mondiale (DRM); System Specification;

2 ETSI TS 102 349, Digital Radio Mondiale (DRM); Receiver Status and Control Interface (RSCI);

3 ITU-R BS.1615-1, *"Planning parameters" for digital sound broadcasting at frequencies below 30 MHz*;

4 EBU-Tech 3330, Technical Base for DRM Services Coverage Planning;

5 DRM Introduction and Implementation Guide, Revision 2, September 2013;

6 ITU-R P.1321, *Propagation factors affecting systems using digital modulation techniques at LF and MF*;

7 ITU-R P.386-7, *Ground-wave propagation curves for frequencies between 10 kHz and 30 MHz*;

8 ITU-R P.1147-2, *Prediction of sky-wave field strength at frequencies between 150 kHz and 1700 kHz*;

9 ITU-R P.832-2, *World Atlas of Ground Conductivities*;

10 ITU-R BS.703, *Characteristics of AM sound broadcasting reference receivers for planning purposes*;

11 ITU Radio communication Study Groups, Document 6E/175, 18 March 2005.

# APPENDIX A

TABLE 16

**Static Antenna Measurement Test Point Details**

| Measurement signal and test point description | | | | | | | | | | | Broadcom Antenna Measurements | | | | | | KinStar Antenna Measurements | | | | | | Delta between Broadcom and KinStar Antenna |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Path Details | | Measurement Test and Test Point details | | | | | | | | | POTOMAC INSTRUMENTS FIM-4100 | | | RFmondial RF-SE12 | | | POTOMAC INSTRUMENTS FIM-4100 | | | RFmondial RF-SE12 | | | |
| | | | | | | | | | | | Field Strength | | | Field Strength | | | Field Strength | | | Field Strength | | | Delta |
| Distance (m) | Azimuth (°) Test Point to Transmitter | Test No. | Test Point No. | Measurement test point description | Test Point Antenna Height (m) | Test Antenna (Type) | Long (Xadm) (East) | Lat (Yadm) (South) | Rx freq (MHz) | Rx polarization | Field strength measurement (dBμV/m) | Predicted FSR (dBμV/m) | Delta btw Actual & Predicted (Only dB μV measurement value) | Field strength measurement (dBμV/m) | Predicted FSR (dBμV/m) | Delta btw Actual & Predicted (Only dB μV measurement value) | Field strength measurement (dBμV/m) | Predicted FSR (dBμV/m) | Delta btw Actual & Predicted (Only dB μV measurement value) | Field strength measurement (dBμV/m) | Predicted FSR (dBμV/m) | Delta btw Actual & Predicted (Only dB μV measurement value) | Delta between Broadcom and KinStar Antenna |
| 1020 | 0° | TEST01 | TP01 | Kameeldrift area | 1.5 | Loop Antenna | 28.19017 | 25.39424 | 1.44 | V | 117.10 | 110.1 | 7.0 | 115.60 | 110.1 | 5.5 | 116.90 | 110.1 | 6.8 | 114.00 | 110.1 | 3.9 | 0.2 |
| 1281 | 45° | TEST02 | TP02 | Kameeldrift area | 1.5 | Loop Antenna | 28.19379 | 25.39418 | 1.44 | V | 115.00 | 107.5 | 7.5 | 115.80 | 107.5 | 8.3 | 115.70 | 107.5 | 8.2 | 115.60 | 107.5 | 8.1 | -0.7 |
| 1000 | 90° | TEST03 | TP03 | Kameeldrift area | 1.5 | Loop Antenna | 28.19445 | 25.40118 | 1.44 | V | 116.00 | 110.3 | 5.7 | 117.60 | 110.3 | 7.3 | 114.80 | 110.3 | 4.5 | 117.10 | 110.3 | 6.8 | 1.2 |
| 1131 | 135° | TEST04 | TP04 | Kameeldrift area | 1.5 | Loop Antenna | 28.19359 | 25.40383 | 1.44 | V | 116.40 | 108.9 | 7.5 | 116.50 | 108.9 | 7.6 | 115.50 | 108.9 | 6.6 | 115.60 | 108.9 | 6.7 | 0.9 |
| 1000 | 180° | TEST05 | TP05 | Kameeldrift area | 1.5 | Loop Antenna | 28.19086 | 25.40454 | 1.44 | V | 117.50 | 110.3 | 7.2 | 120.00 | 110.3 | 9.7 | 117.00 | 110.3 | 6.7 | 119.00 | 110.3 | 8.7 | 0.5 |
| 1000 | 225° | TEST06 | TP06 | Kameeldrift area | 1.5 | Loop Antenna | 28.18399 | 25.40335 | 1.44 | V | 118.00 | 110.3 | 7.7 | 118.70 | 110.3 | 8.4 | 117.20 | 110.3 | 6.9 | 118.50 | 110.3 | 8.2 | 0.8 |
| 1300 | 270° | TEST07 | TP07 | Kameeldrift area | 1.5 | Loop Antenna | 28.18201 | 25.40130 | 1.44 | V | 113.30 | 107.3 | 6.0 | 114.50 | 107.3 | 7.2 | 112.40 | 107.3 | 5.1 | 114.60 | 107.3 | 7.3 | 0.9 |
| 1273 | 315° | TEST08 | TP08 | Kameeldrift area | 1.5 | Loop Antenna | 28.18365 | 25.39459 | 1.44 | V | 115.10 | 107.6 | 7.5 | 114.20 | 107.6 | 6.6 | 114.80 | 107.6 | 7.2 | 114.10 | 107.6 | 6.5 | 0.3 |
| 4800 | 0° | TEST09 | TP09 | Rynoue AH | 1.5 | Loop Antenna | 28.19069 | 25.37388 | 1.44 | V | 102.00 | 91.1 | 10.9 | | | | 100.80 | 91.1 | 9.7 | 102.30 | 91.1 | 11.2 | 1.2 |
| 4952 | 45° | TEST10 | TP10 | Roodeplaat Dam Nature Reserve | 1.5 | Loop Antenna | 28.21077 | 25.38171 | 1.44 | V | 102.80 | 89.8 | 13.0 | | | | 98.10 | 89.8 | 8.3 | 99.40 | 89.8 | 9.6 | 4.7 |
| 5304 | 90° | TEST11 | TP11 | Baviaanspoort | 1.5 | Loop Antenna | 28.22162 | 25.40176 | 1.44 | V | 102.80 | 88.7 | 14.1 | | | | 98.30 | 88.7 | 9.6 | 99.50 | 88.7 | 10.8 | 4.5 |
| 5021 | 135° | TEST12 | TP12 | Mamelodi | 1.5 | Loop Antenna | 28.21200 | 25.42076 | 1.44 | V | 95.40 | 89.6 | 5.8 | | | | 90.30 | 89.6 | 0.7 | 91.20 | 89.6 | 1.6 | 5.1 |
| 5100 | 180° | TEST13 | TP13 | Eersterus | 1.5 | Loop Antenna | 28.19092 | 25.42590 | 1.44 | V | 97.79 | 89.3 | 8.5 | | | | 94.30 | 89.3 | 5.0 | 92.90 | 89.3 | 3.6 | 3.5 |
| 5166 | 225° | TEST14 | TP14 | Ekklesia | 1.5 | Loop Antenna | 28.16540 | 25.42073 | 1.44 | V | 100.36 | 89.1 | 11.3 | | | | 98.50 | 89.1 | 9.4 | 97.40 | 89.1 | 8.3 | 1.9 |
| 4701 | 270° | TEST15 | TP15 | Montana Gardens | 1.5 | Loop Antenna | 28.16185 | 25.40133 | 1.44 | V | 100.79 | 90.5 | 10.3 | | | | 99.80 | 90.5 | 9.3 | 100.00 | 90.5 | 9.5 | 1.0 |
| 5048 | 315° | TEST16 | TP16 | N1 Highway | 1.5 | Loop Antenna | 28.16374 | 25.38449 | 1.44 | V | 99.45 | 89.5 | 10.0 | | | | 98.10 | 89.5 | 8.6 | 97.70 | 89.5 | 8.2 | 1.4 |
| 1603 | 0° | TEST17 | TP17 | Kameeldrift area | 1.5 | Loop Antenna | 28.19025 | 25.39209 | 1.44 | V | 113.96 | 104.8 | 9.2 | | | | 113.40 | 104.9 | 8.5 | 115.30 | 104.9 | 10.4 | 0.6 |
| 2263 | 45° | TEST18 | TP18 | Kameeldrift area | 1.5 | Loop Antenna | 28.20046 | 25.39210 | 1.44 | V | 108.30 | 100.6 | 7.7 | | | | 106.90 | 100.6 | 6.3 | 109.00 | 100.6 | 8.4 | 1.4 |
| 1903 | 90° | TEST19 | TP19 | Kameeldrift area | 1.5 | Loop Antenna | 28.20168 | 25.40167 | 1.44 | V | 105.00 | 102.8 | 2.2 | | | | 109.20 | 102.8 | 6.4 | 102.80 | 102.8 | 0.0 | -4.2 |
| 1910 | 135° | TEST20 | TP20 | Kameeldrift area | 1.5 | Loop Antenna | 28.19567 | 25.40597 | 1.44 | V | 108.90 | 102.7 | 6.2 | | | | 107.50 | 102.7 | 4.8 | 106.40 | 102.7 | 3.7 | 1.4 |
| 2200 | 180° | TEST21 | TP21 | Kameeldrift area | 1.5 | Loop Antenna | 28.19089 | 25.41243 | 1.44 | V | 109.66 | 100.9 | 8.8 | | | | 109.40 | 100.9 | 8.5 | 108.50 | 100.9 | 7.6 | 0.3 |
| 1910 | 225° | TEST22 | TP22 | Kameeldrift area | 1.5 | Loop Antenna | 28.18175 | 25.40573 | 1.44 | V | 108.66 | 102.7 | 6.0 | | | | 110.50 | 102.7 | 7.8 | 112.90 | 102.7 | 10.2 | -1.8 |
| 2202 | 270° | TEST23 | TP23 | Kameeldrift area | 1.5 | Loop Antenna | 28.17507 | 25.40167 | 1.44 | V | 109.89 | 100.9 | 9.0 | | | | 108.50 | 100.9 | 7.6 | 108.70 | 100.9 | 7.8 | 1.4 |
| 2263 | 315° | TEST24 | TP24 | Kameeldrift area | 1.5 | Loop Antenna | 28.18091 | 25.39222 | 1.44 | V | 110.80 | 100.6 | 10.2 | | | | 109.40 | 100.6 | 8.8 | 109.10 | 100.6 | 8.5 | 1.4 |
| 608 | 0° | TEST25 | TP25 | Kameeldrift area | 1.5 | Loop Antenna | 28.19102 | 25.39534 | 1.44 | V | 122.44 | 115.6 | 6.8 | | | | 121.80 | 115.6 | 6.2 | 122.50 | 115.6 | 6.9 | 0.6 |
| 500 | 45° | TEST26 | TP26 | Kameeldrift area | 1.5 | Loop Antenna | 28.19177 | 25.39591 | 1.44 | V | 124.35 | 117.6 | 6.8 | | | | 123.30 | 117.7 | 5.6 | 122.90 | 117.7 | 5.2 | 1.1 |
| 600 | 90° | TEST27 | TP27 | Kameeldrift area | 1.5 | Loop Antenna | 28.19297 | 25.40138 | 1.44 | V | 121.80 | 115.8 | 6.0 | | | | 120.90 | 115.8 | 5.1 | 122.20 | 115.8 | 6.4 | 0.9 |
| 500 | 135° | TEST28 | TP28 | Kameeldrift area | 1.5 | Loop Antenna | 28.19202 | 25.40280 | 1.44 | V | 122.32 | 117.6 | 4.7 | | | | 121.20 | 117.7 | 3.5 | 121.40 | 117.7 | 3.7 | 1.1 |
| 500 | 180° | TEST29 | TP29 | Kameeldrift area | 1.5 | Loop Antenna | 28.19068 | 25.40313 | 1.44 | V | 122.74 | 117.6 | 5.1 | | | | 121.30 | 117.7 | 3.6 | 119.70 | 117.7 | 2.0 | 1.4 |
| 640 | 225° | TEST30 | TP30 | Kameeldrift area | 1.5 | Loop Antenna | 28.18515 | 25.40255 | 1.44 | V | 121.85 | 115.1 | 6.8 | | | | 121.30 | 115.1 | 6.2 | 112.40 | 115.1 | -2.7 | 0.5 |
| 700 | 270° | TEST31 | TP31 | Kameeldrift area | 1.5 | Loop Antenna | 28.18432 | 25.40128 | 1.44 | V | 121.01 | 114.2 | 6.8 | | | | 120.20 | 114.2 | 6.0 | 121.50 | 114.2 | 7.3 | 0.8 |
| 412 | 315° | TEST32 | TP32 | Kameeldrift area | 1.5 | Loop Antenna | 28.18535 | 25.40103 | 1.44 | V | 125.13 | 119.6 | 5.5 | | | | 123.90 | 119.6 | 4.3 | 122.40 | 119.6 | 2.8 | 1.2 |
| | | | | | | | | | | | AVERAGE | | 7.7 | | | | | | 6.6 | | | | 1.1 |

# APPENDIX B

FIGURE 56

**Broadcom Antenna north radial route – 16QAM**

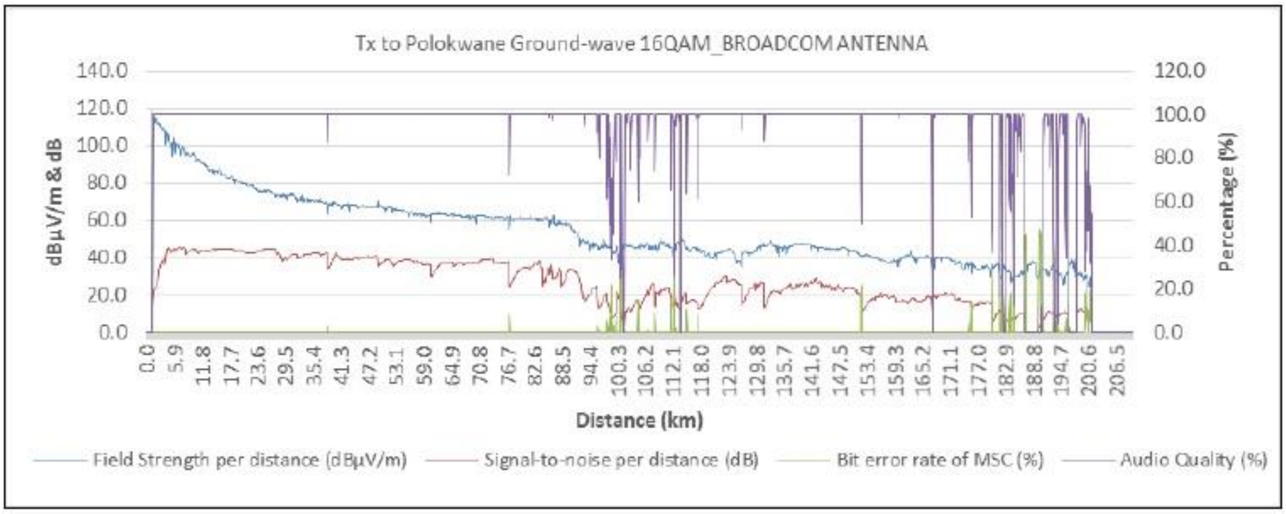



FIGURE 57

**Broadcom Antenna north-east radial route – 16QAM**

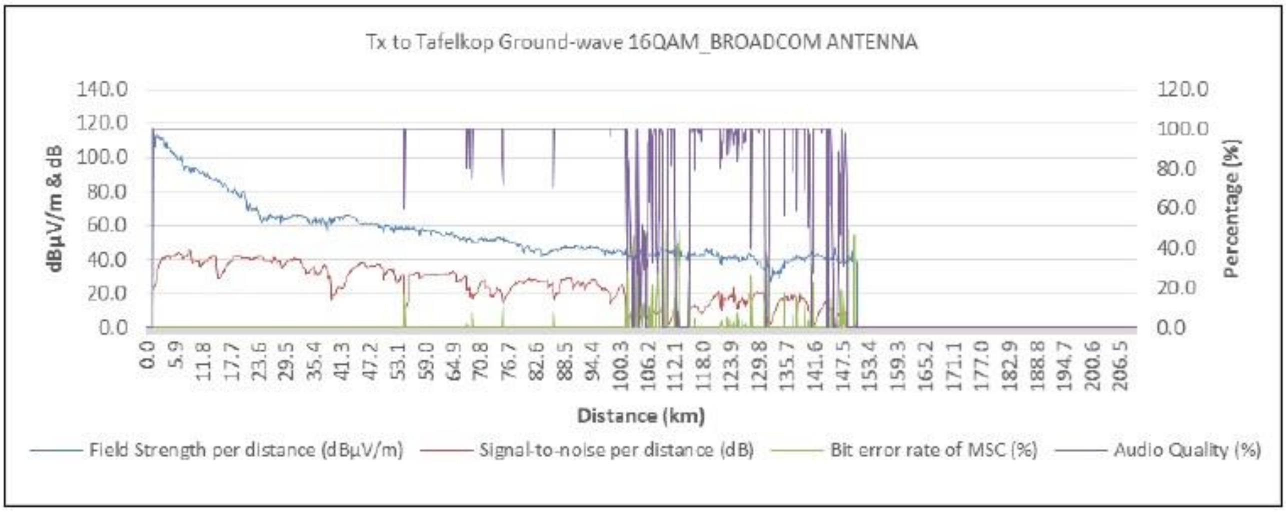


FIGURE 58

**Broadcom Antenna east radial route – 16QAM**

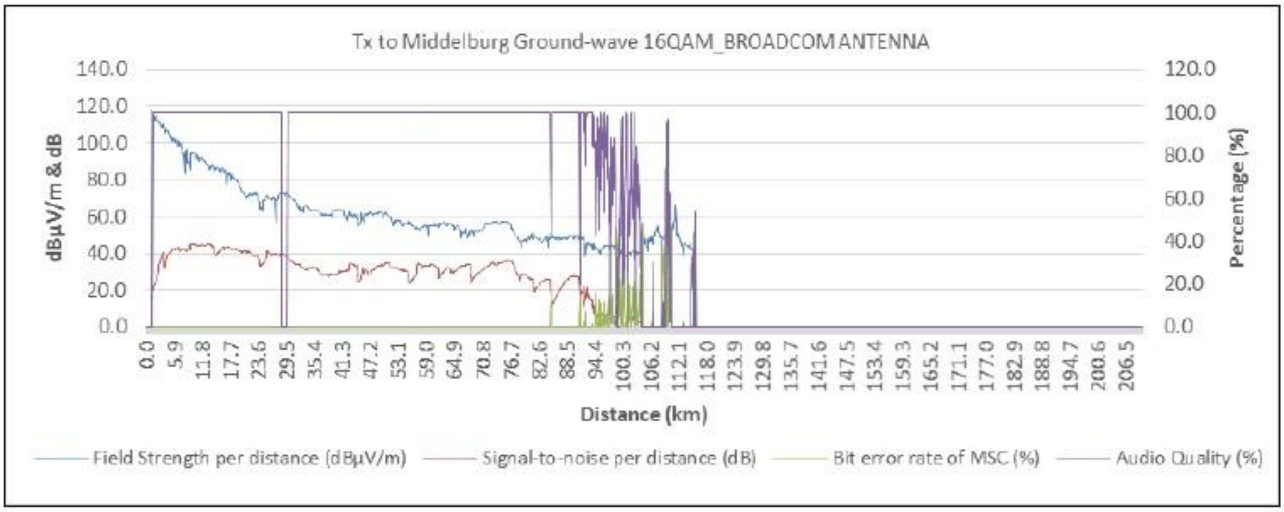



FIGURE 59

**Broadcom Antenna south-east radial route – 16QAM**

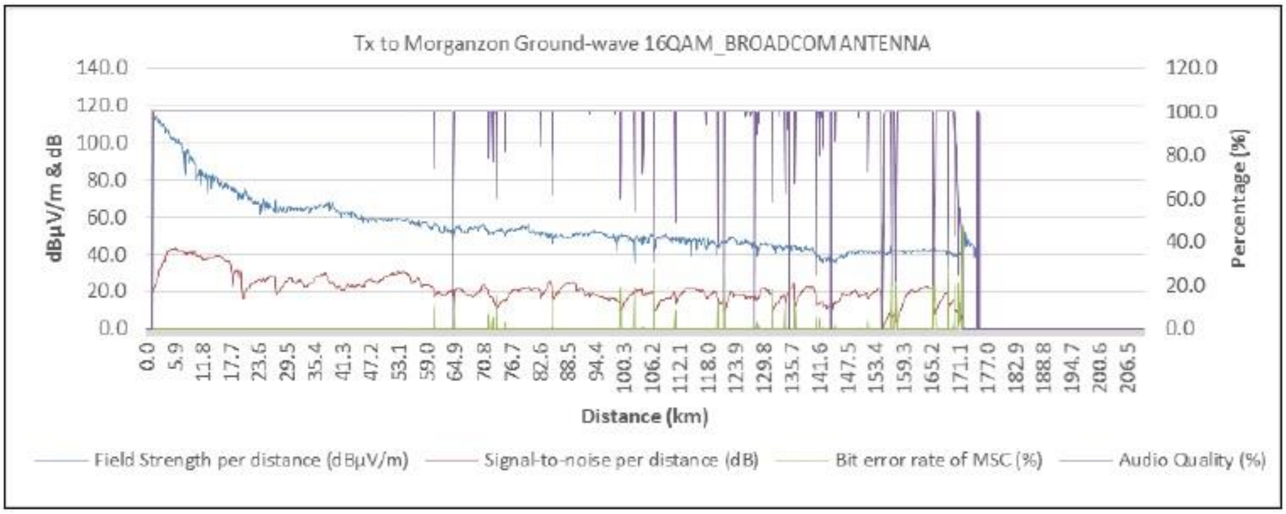


FIGURE 60

**Broadcom Antenna south radial route – 16QAM**

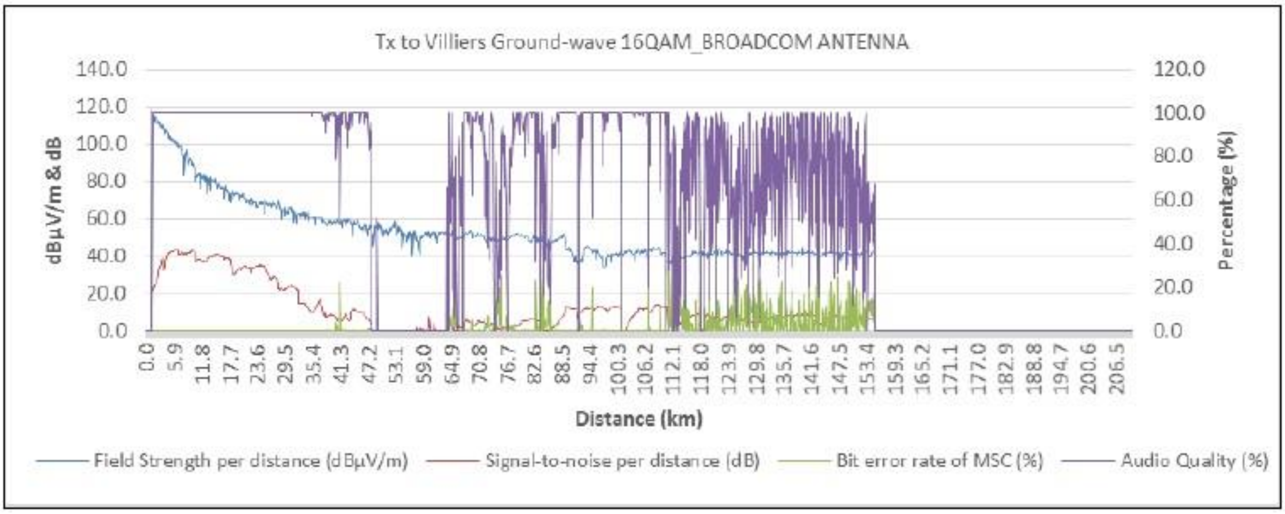



FIGURE 61

**Broadcom Antenna south-west radial route – 16QAM**

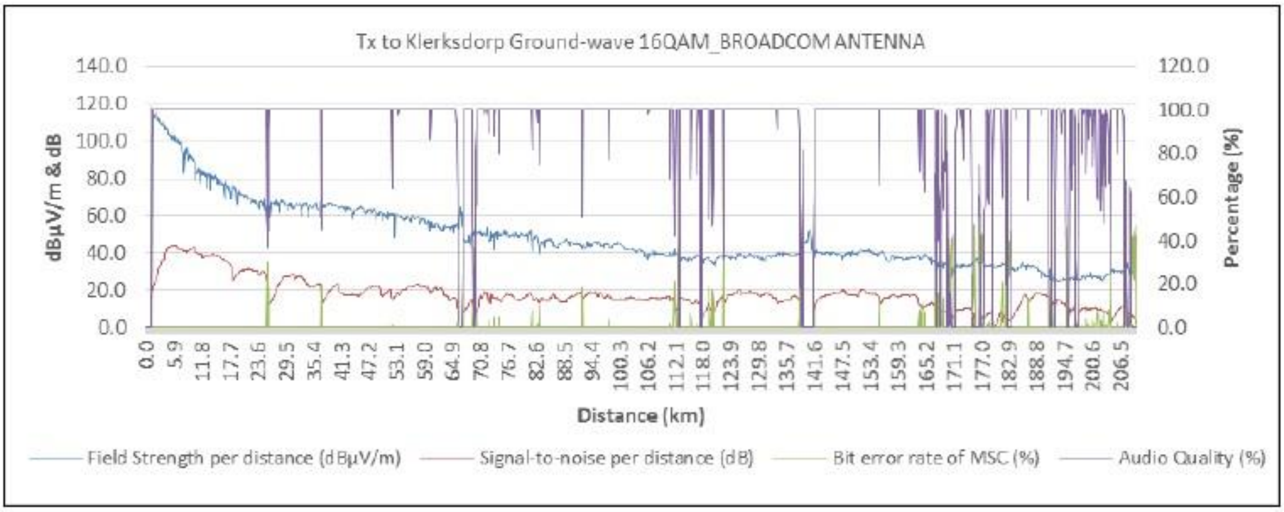


FIGURE 62

**Broadcom Antenna west radial route – 16QAM**

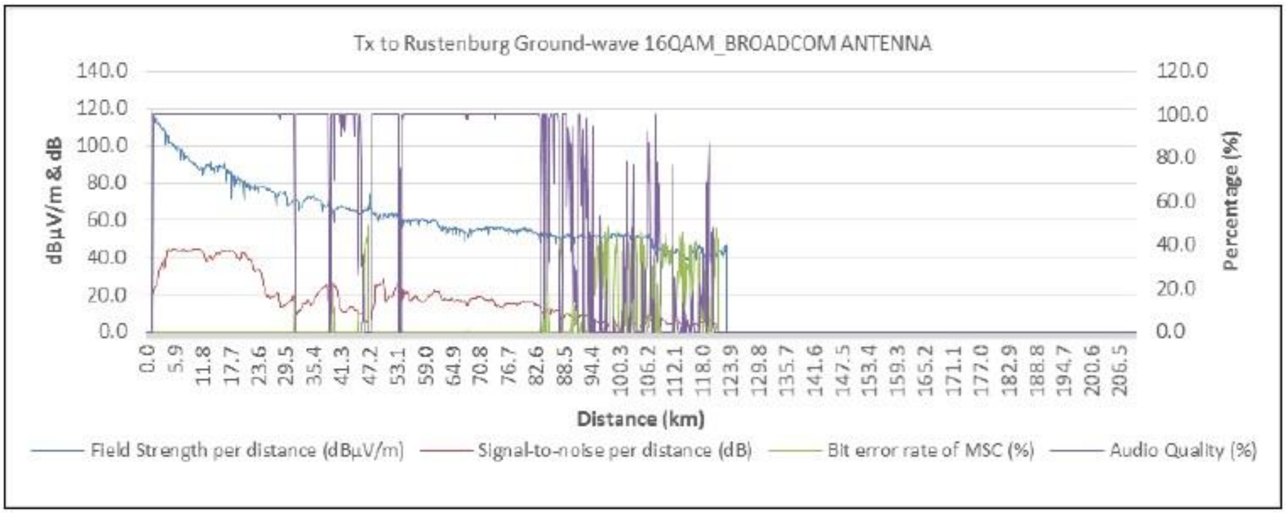



FIGURE 63

**Broadcom Antenna north-west radial route – 16QAM**

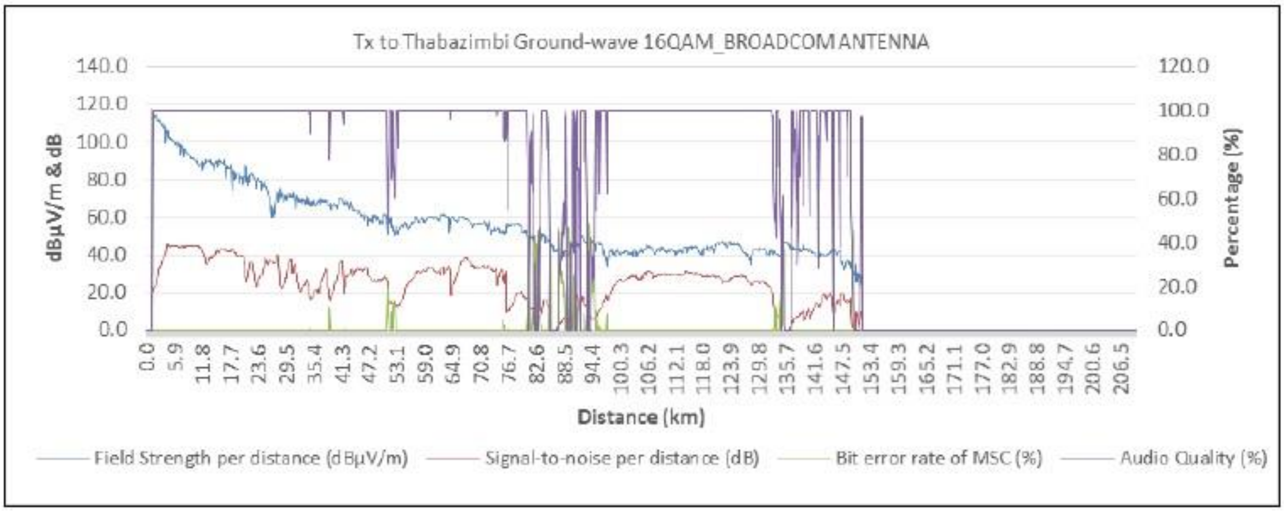


FIGURE 64

**Broadcom Antenna north radial route – 64QAM**

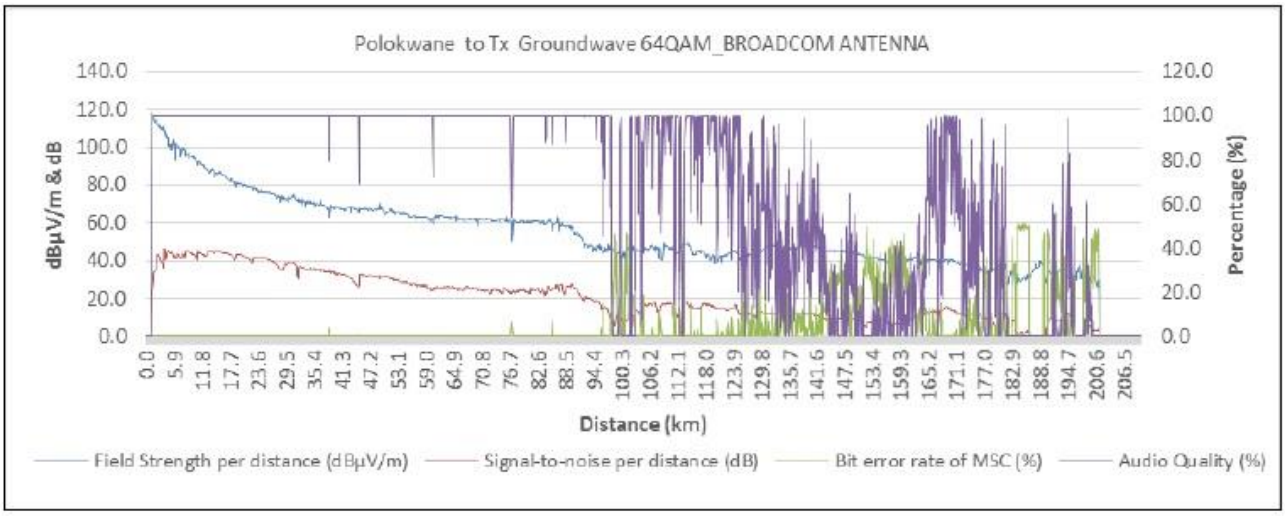



FIGURE 65

**Broadcom Antenna north-east radial route – 64QAM**

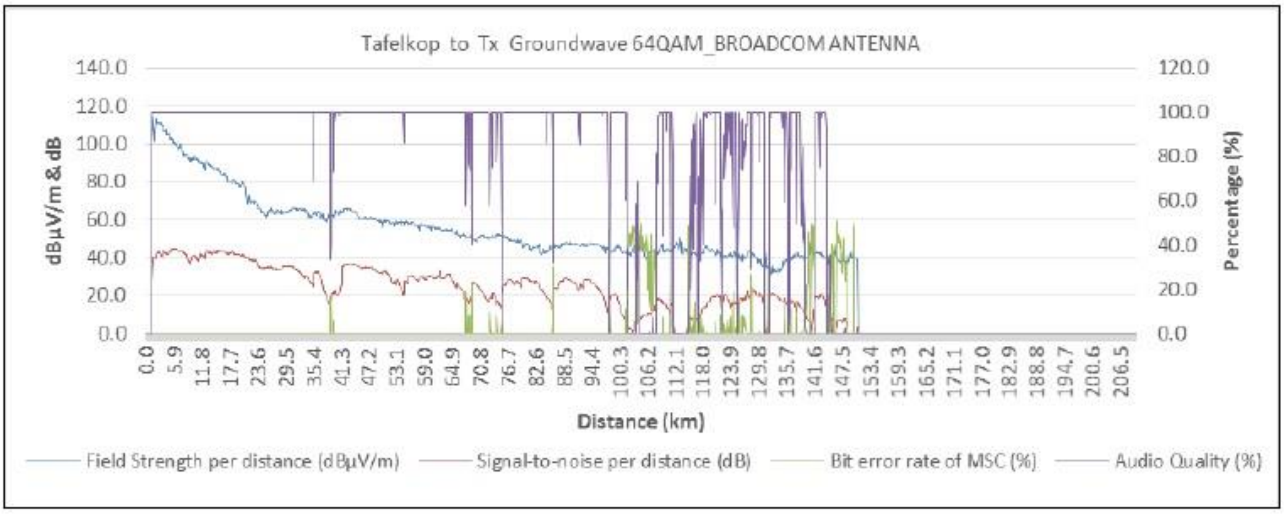


FIGURE 66

**Broadcom Antenna east radial route – 64QAM**

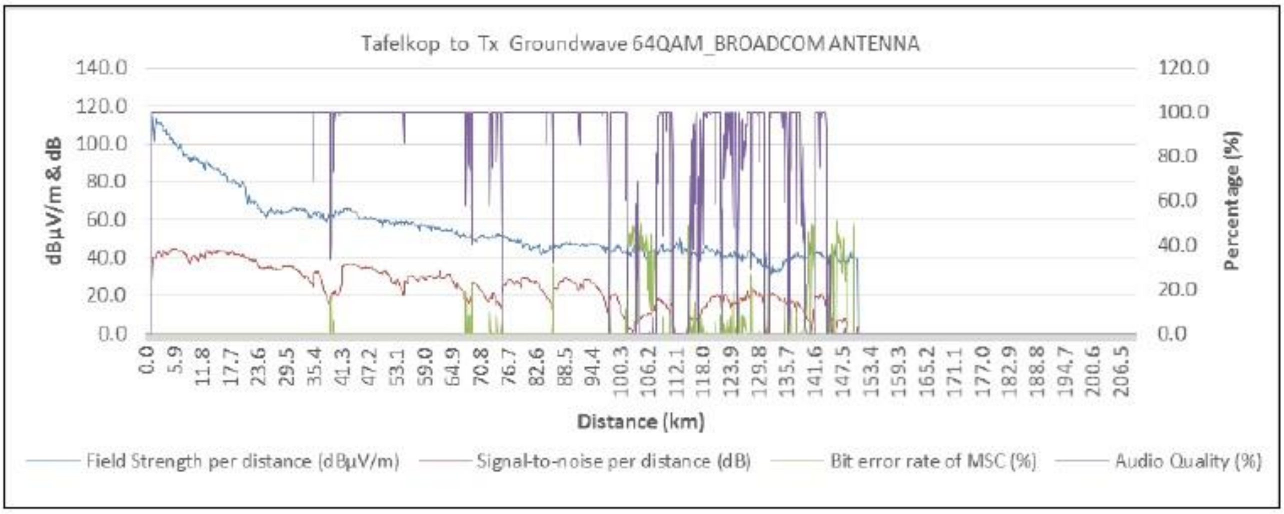



FIGURE 67

**Broadcom Antenna south-east radial route – 64QAM**

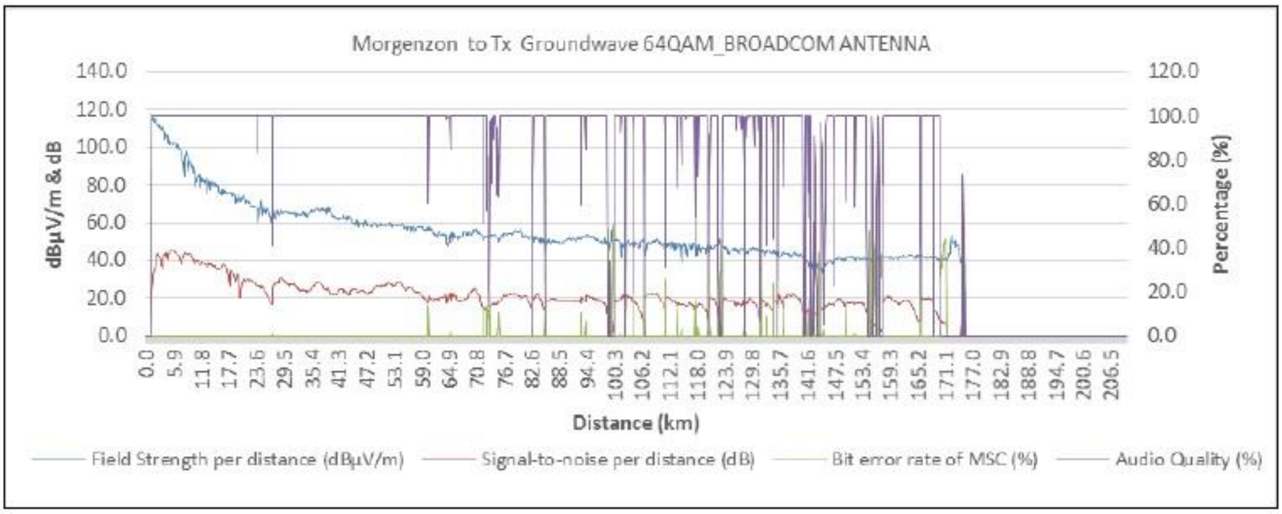


FIGURE 68

**Broadcom Antenna south radial route – 64QAM**

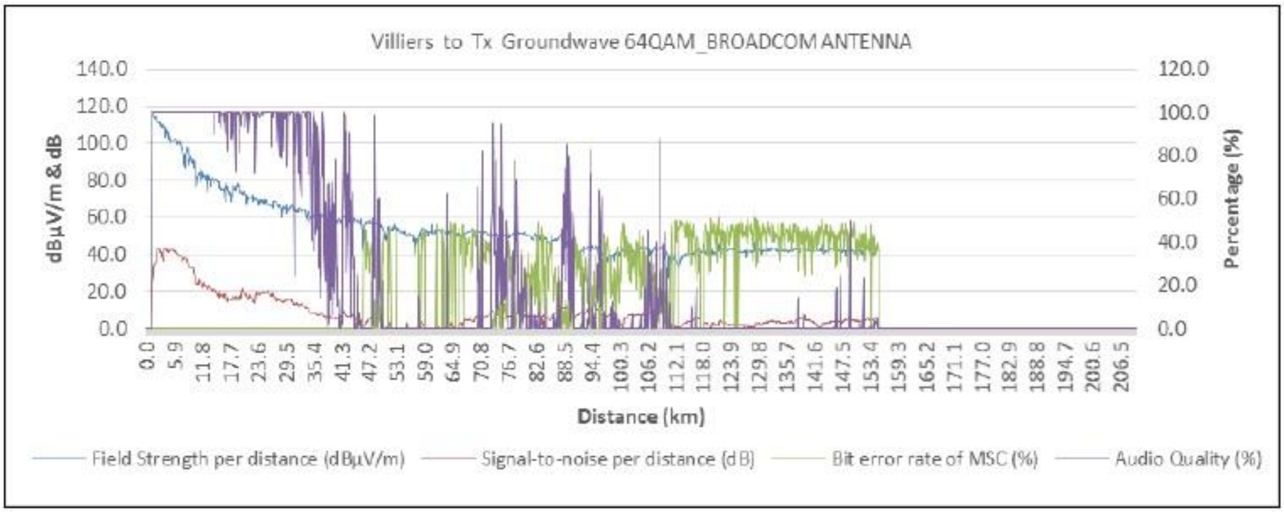



FIGURE 69

**Broadcom Antenna south-west radial route – 64QAM**

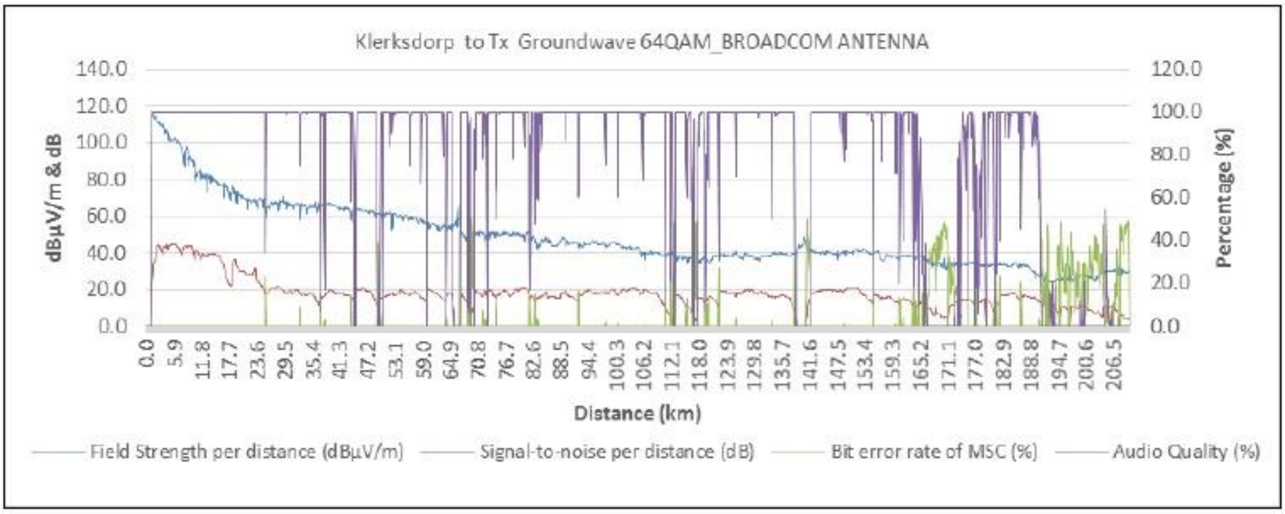


FIGURE 70

**Broadcom Antenna west radial route – 64QAM**

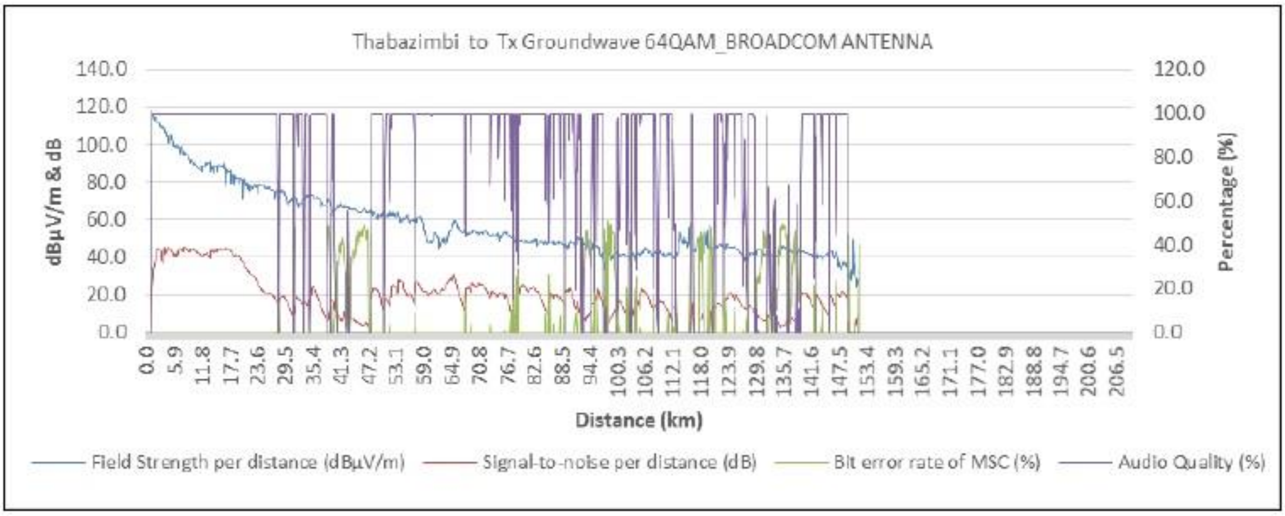
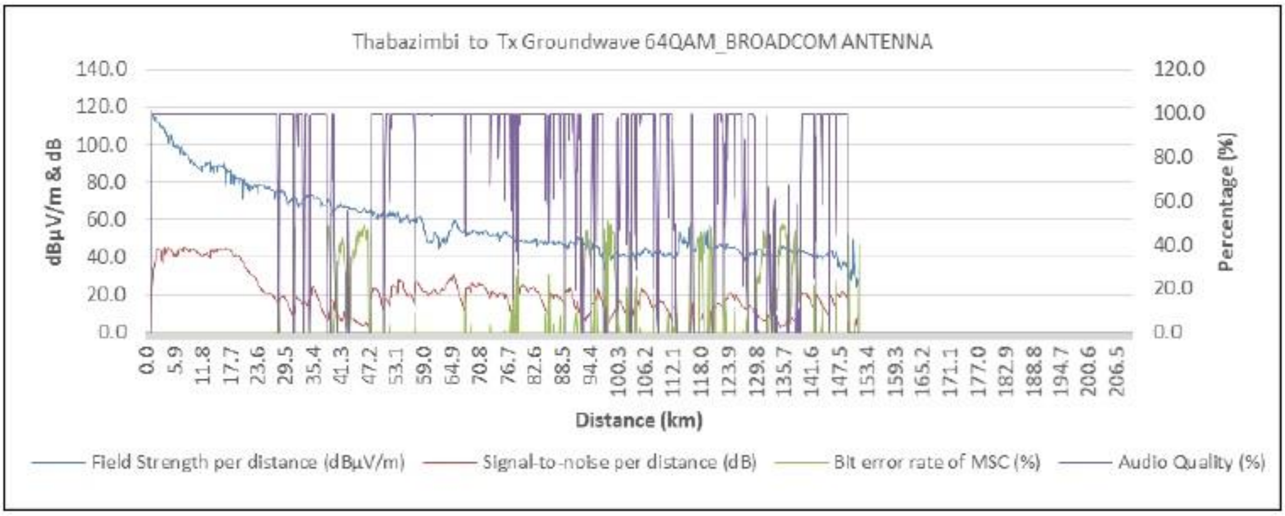



FIGURE 71

**Broadcom Antenna north-west radial route – 64QAM**



# APPENDIX C

FIGURE 72

**KinStar antenna north radial route – 16QAM**

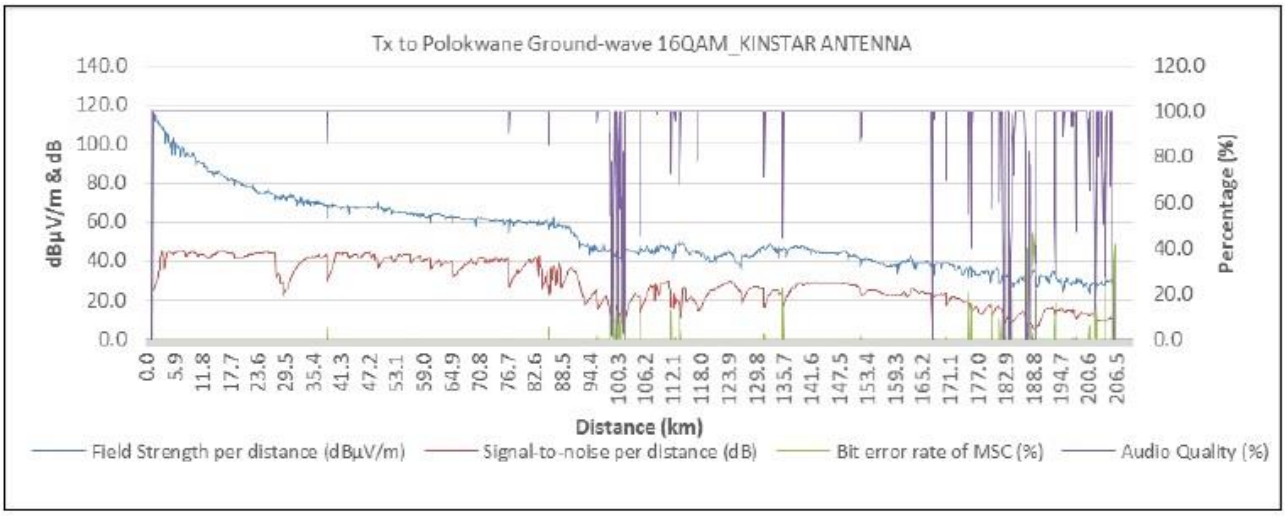



FIGURE 73

**KinStar antenna north-east radial route – 16QAM**

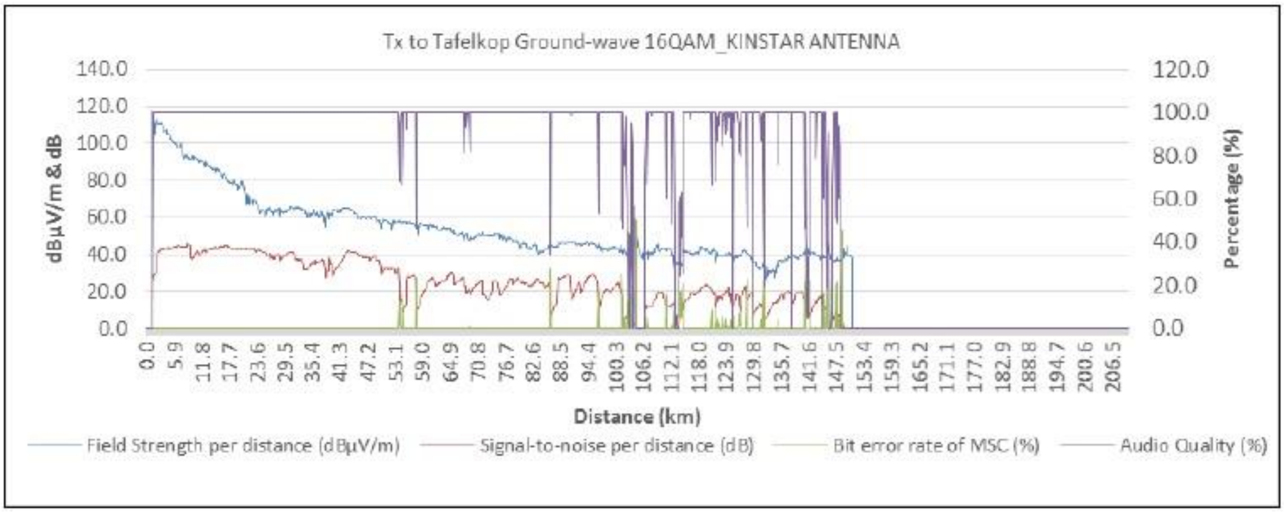


FIGURE 74

**KinStar antenna east radial route – 16QAM**

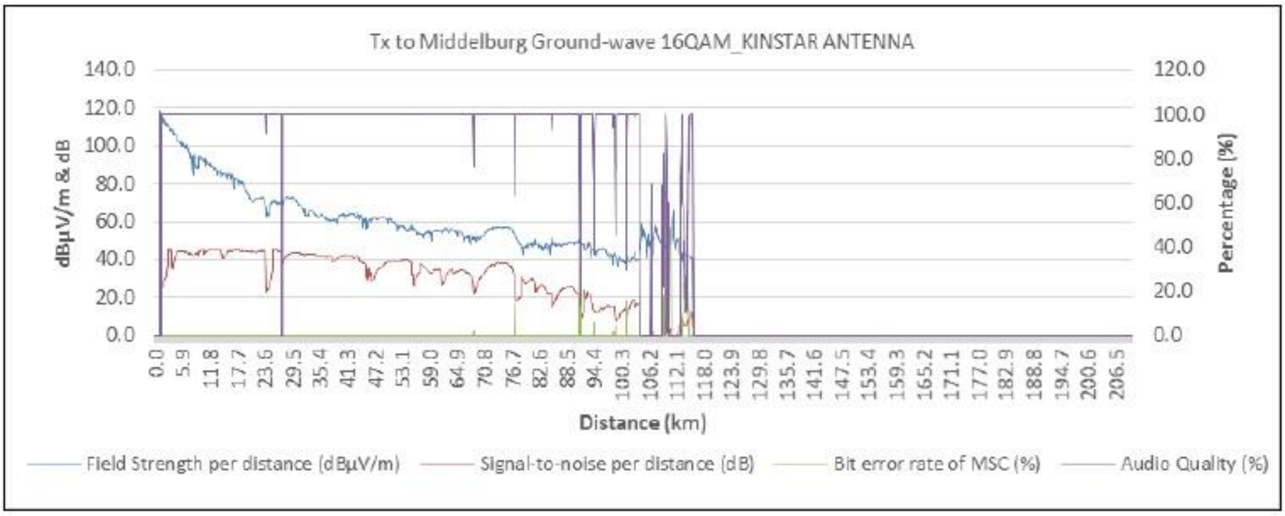



FIGURE 75

**KinStar antenna south-east radial route – 16QAM**

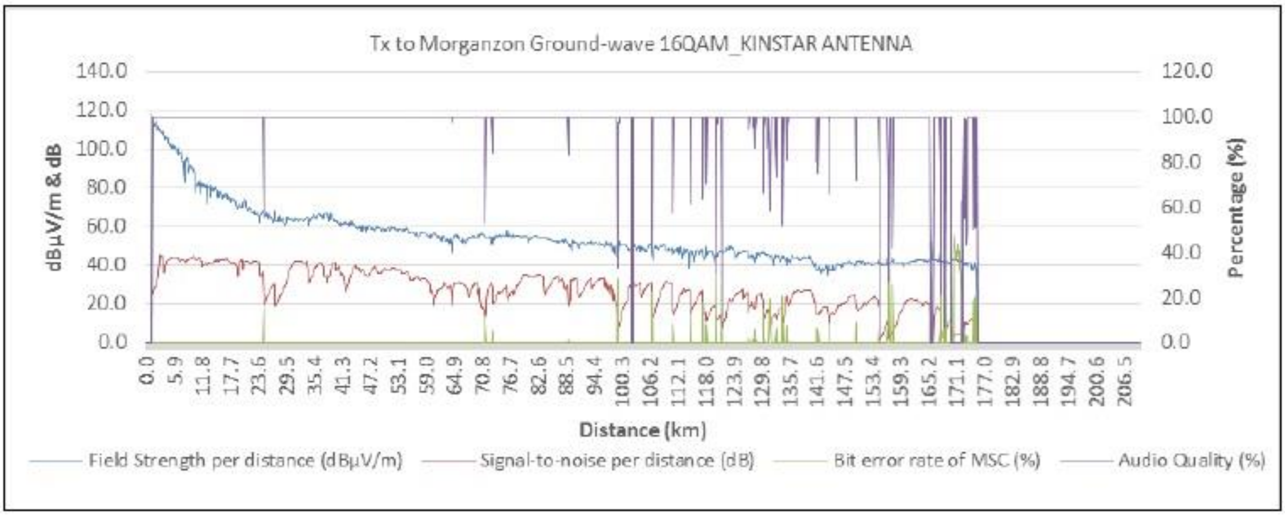


FIGURE 76

**KinStar antenna south radial route – 16QAM**

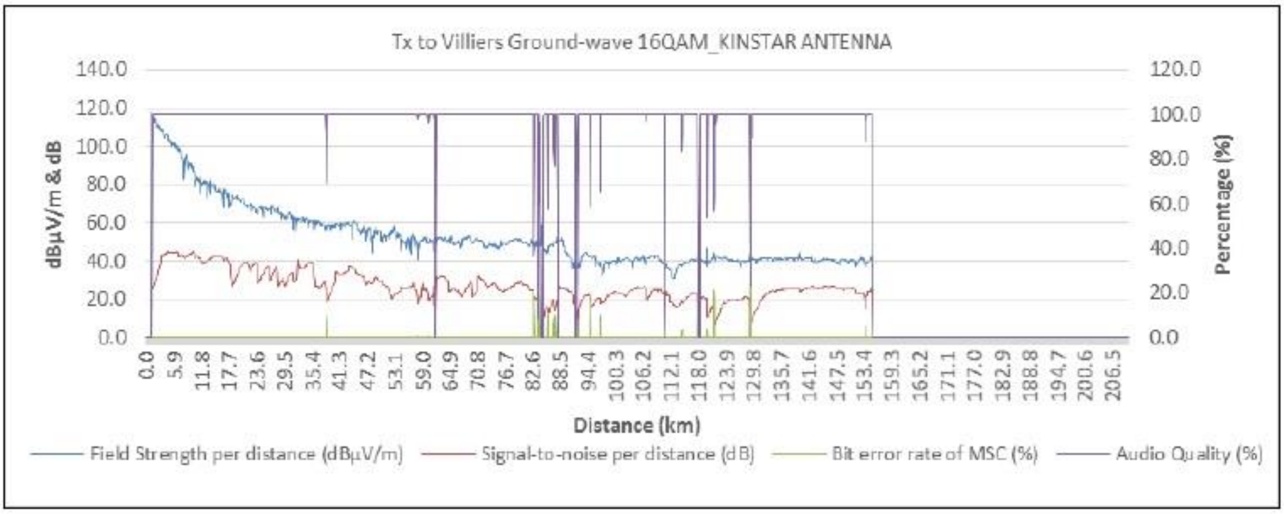



FIGURE 77

**KinStar antenna south-west radial route – 16QAM**

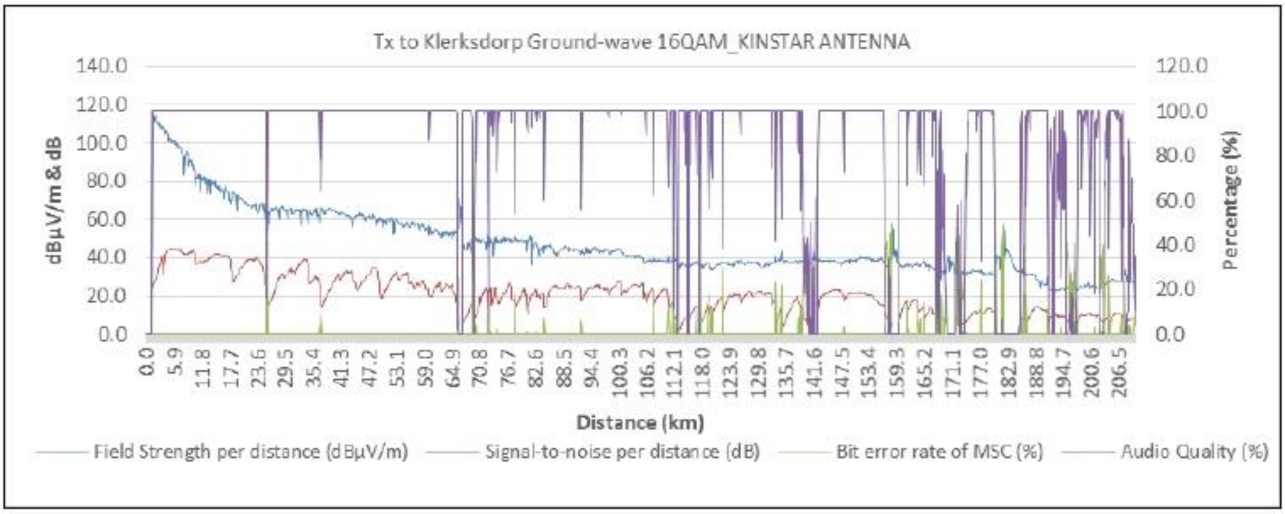


FIGURE 78

**KinStar antenna west radial route – 16QAM**

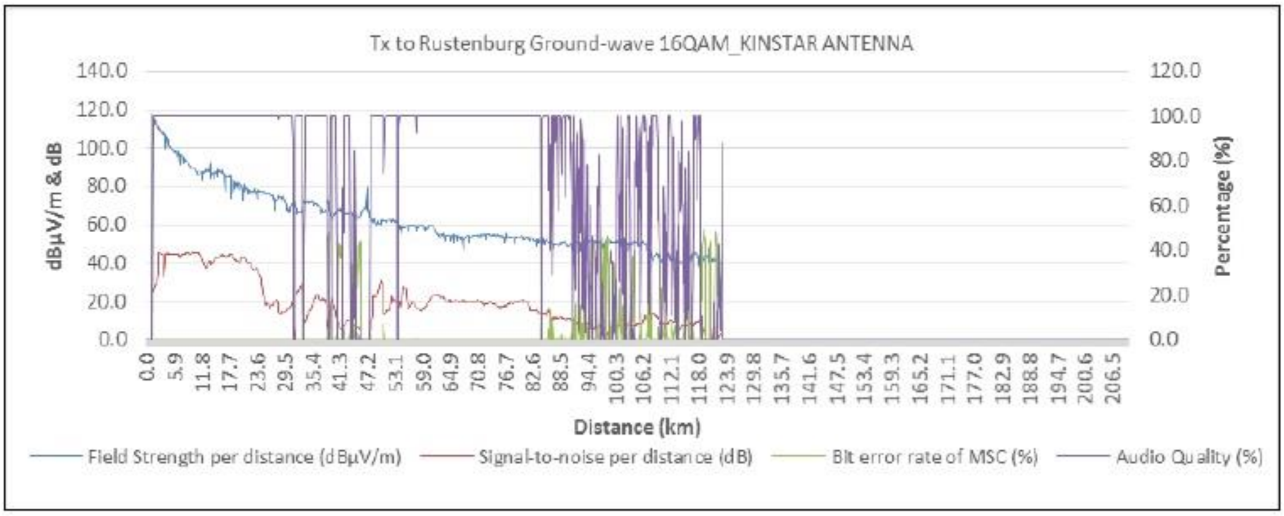



FIGURE 79

**KinStar antenna north-west radial route – 16QAM**

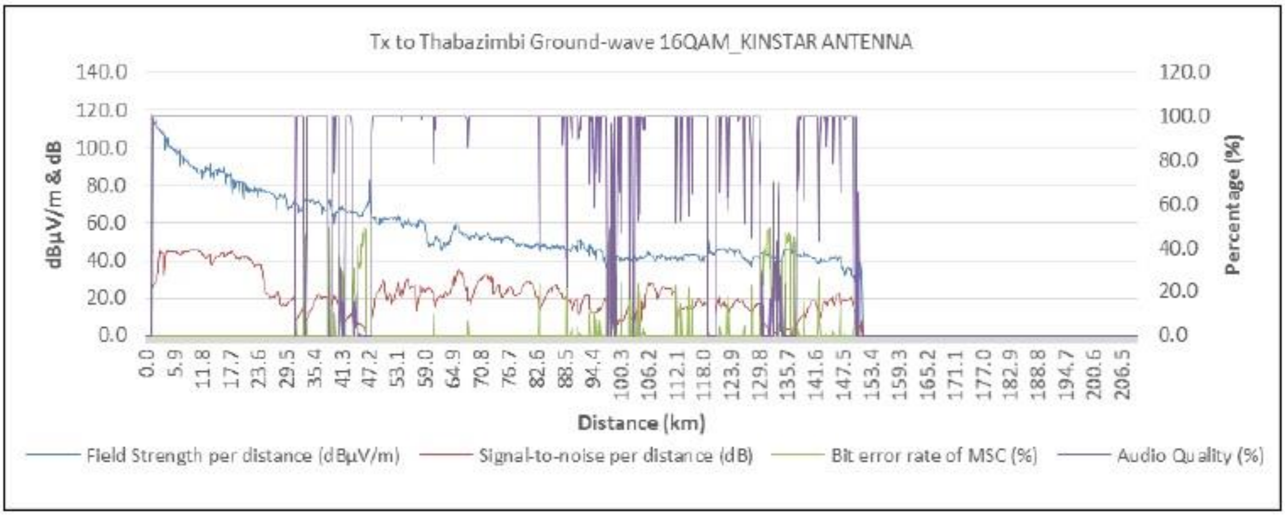


FIGURE 80

**KinStar antenna north radial route – 64QAM**

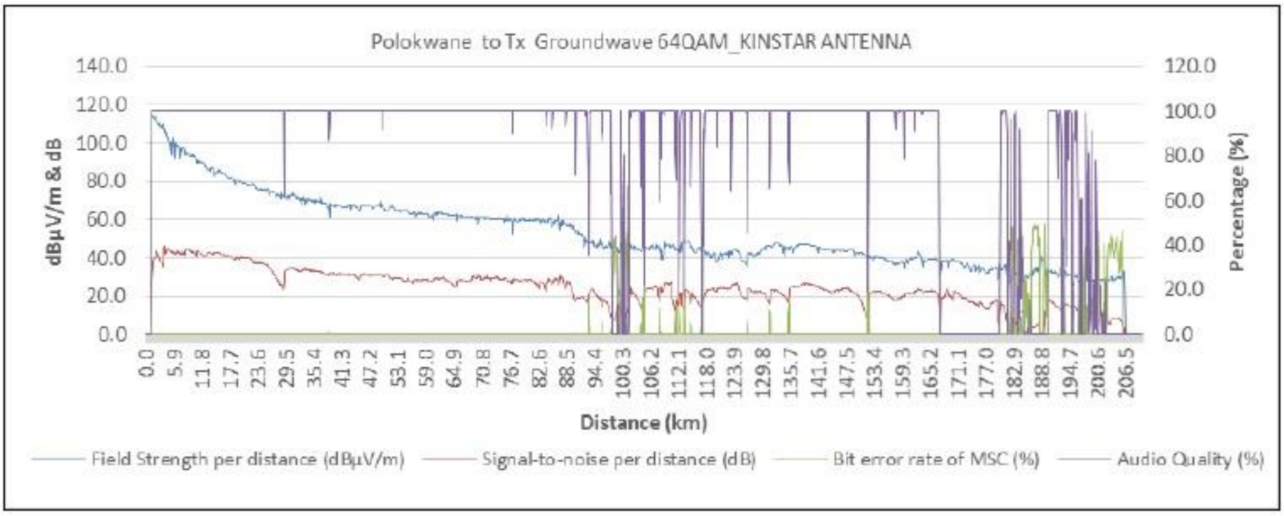



FIGURE 81

**KinStar antenna north-east radial route – 64QAM**

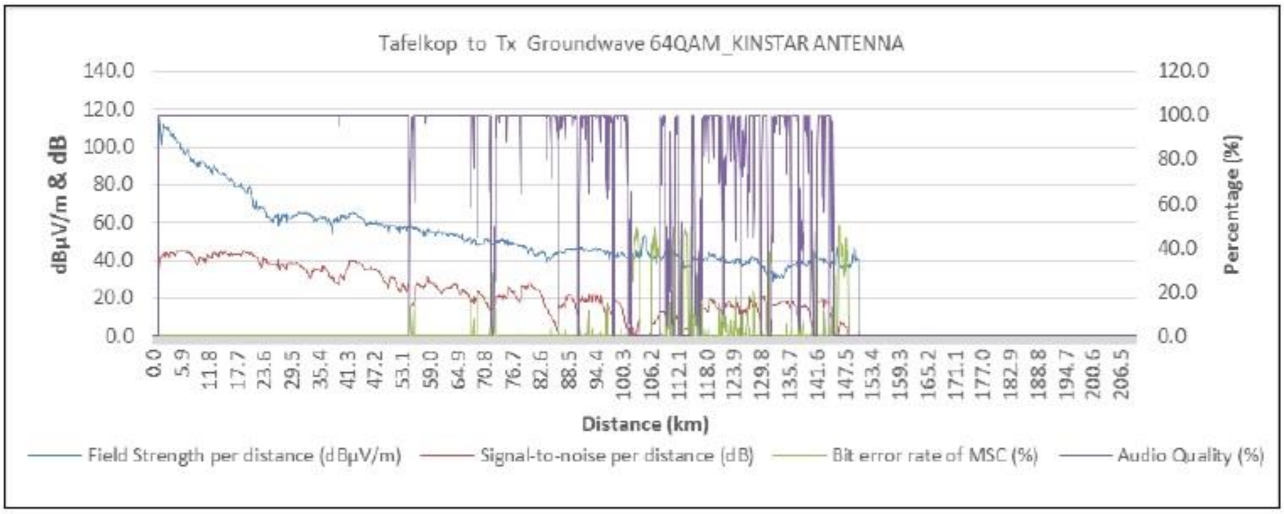


FIGURE 82

**KinStar antenna east radial route – 64QAM**

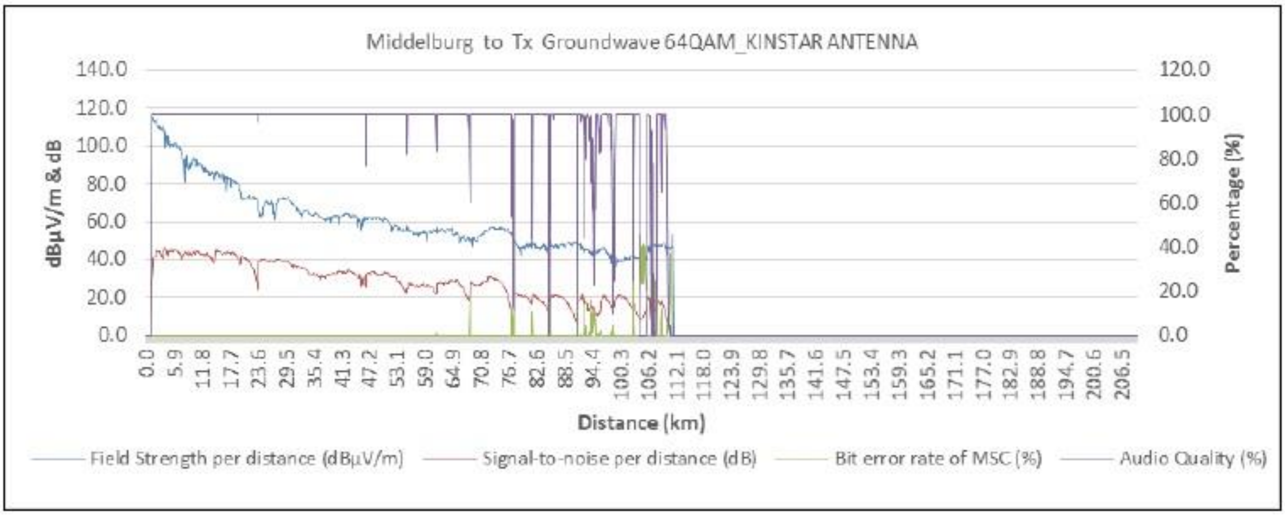



FIGURE 83

**KinStar antenna south-east radial route – 64QAM**

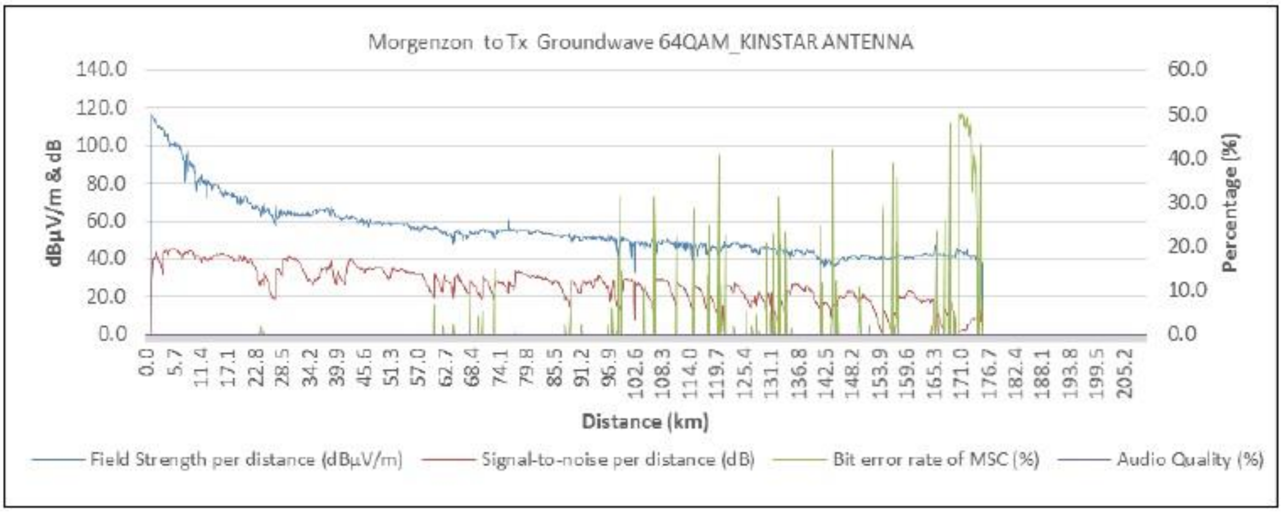


FIGURE 84

**KinStar antenna south radial route – 64QAM**

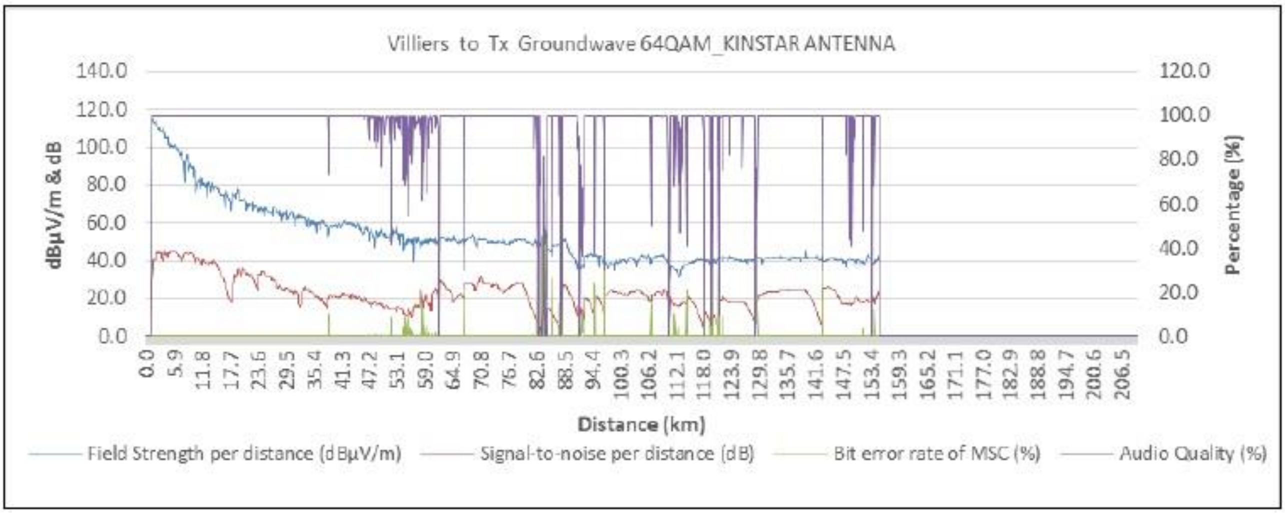



FIGURE 85

**KinStar antenna south-west radial route – 64QAM**

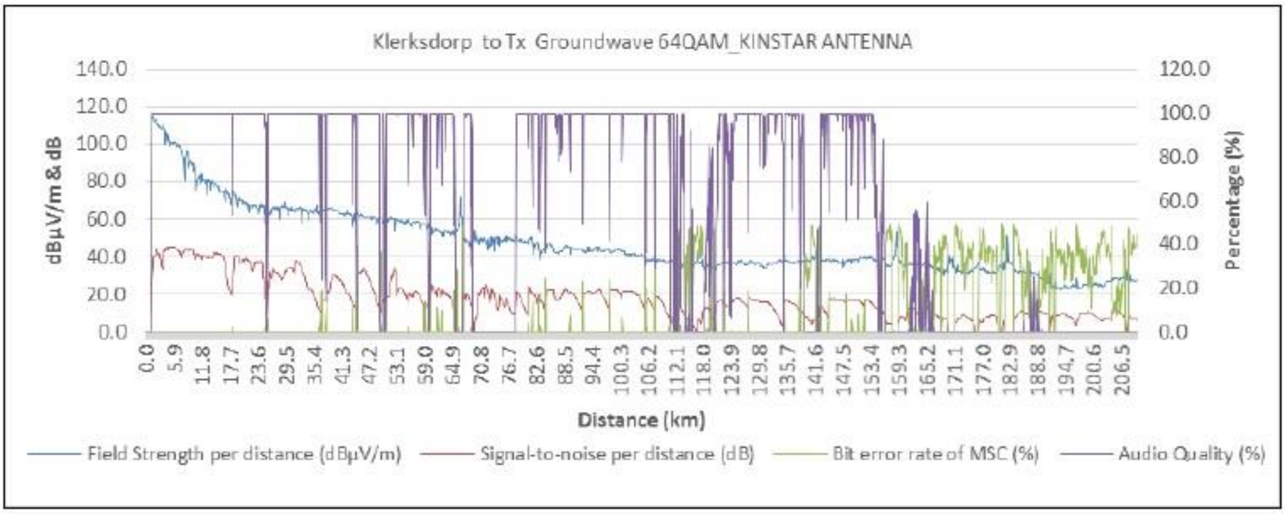


FIGURE 86

**KinStar antenna west radial route – 64QAM**

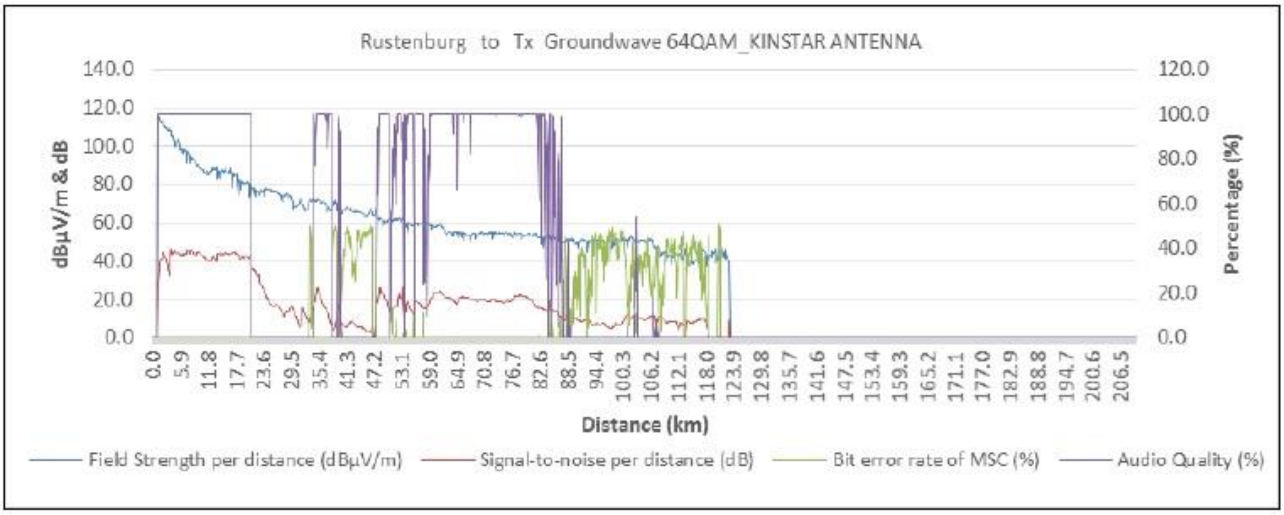
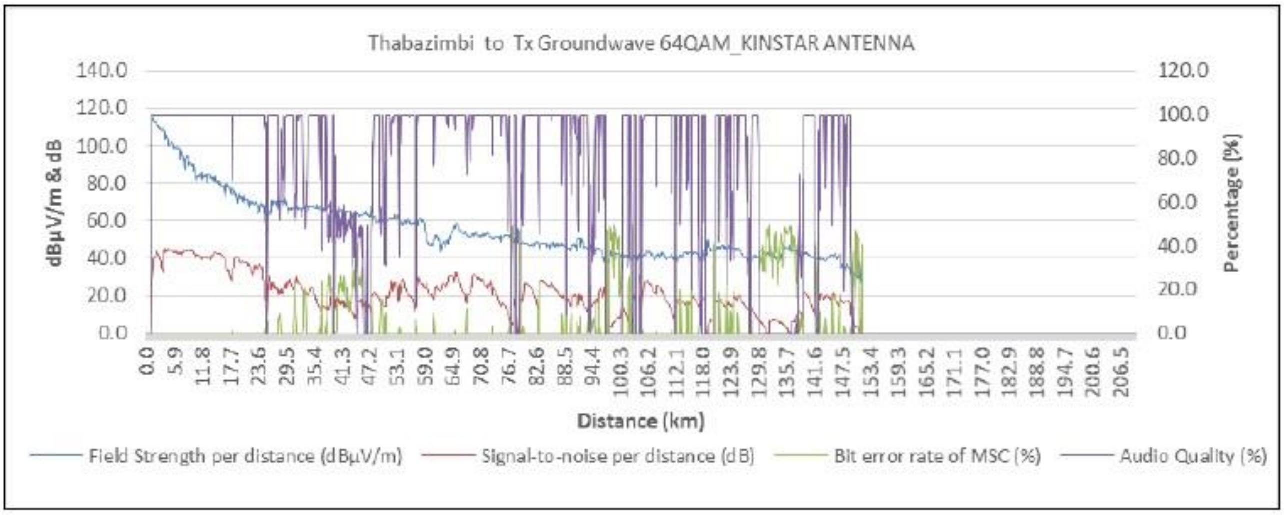



FIGURE 87

**KinStar antenna north-west radial route – 64QAM**



# APPENDIX D

FIGURE 88

**Broadcom Antenna north radial route – 16QAM**

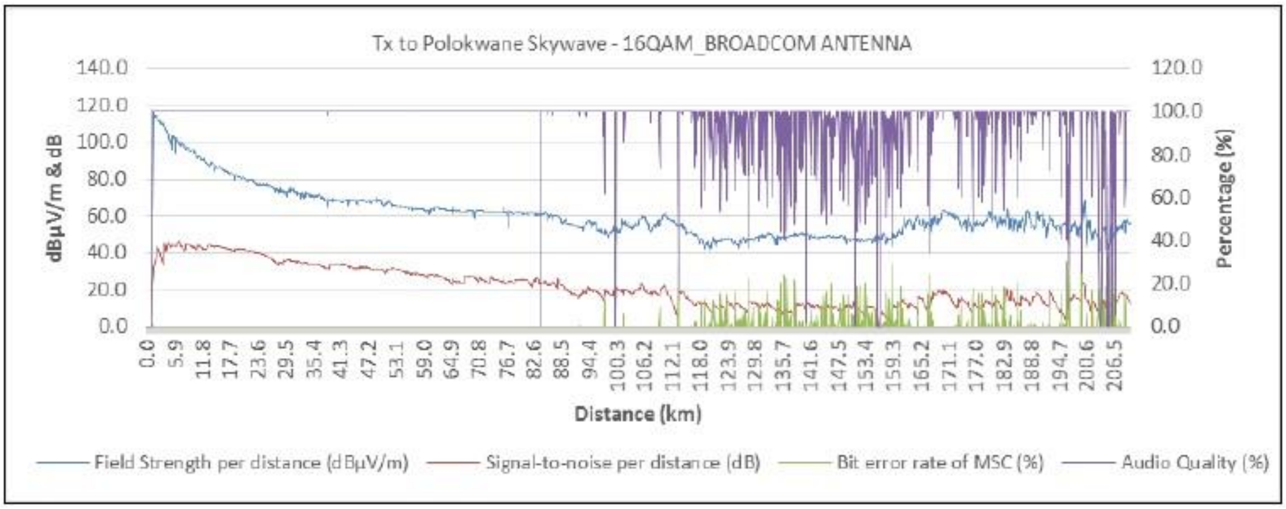



FIGURE 89

**Broadcom Antenna north radial route – 64QAM**

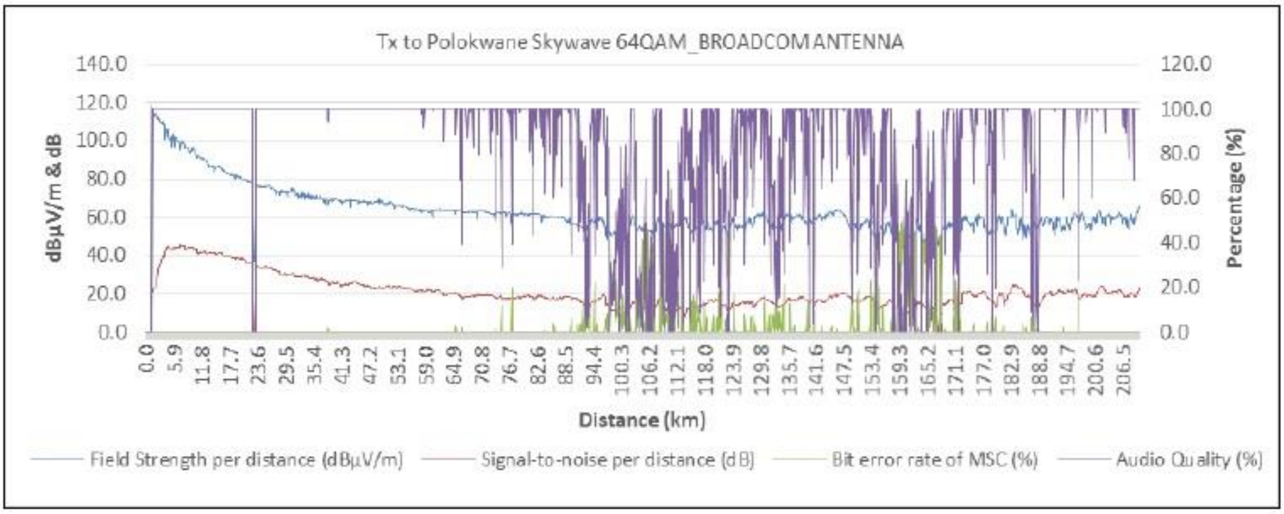


FIGURE 90

**KinStar antenna north radial route – 16QAM**

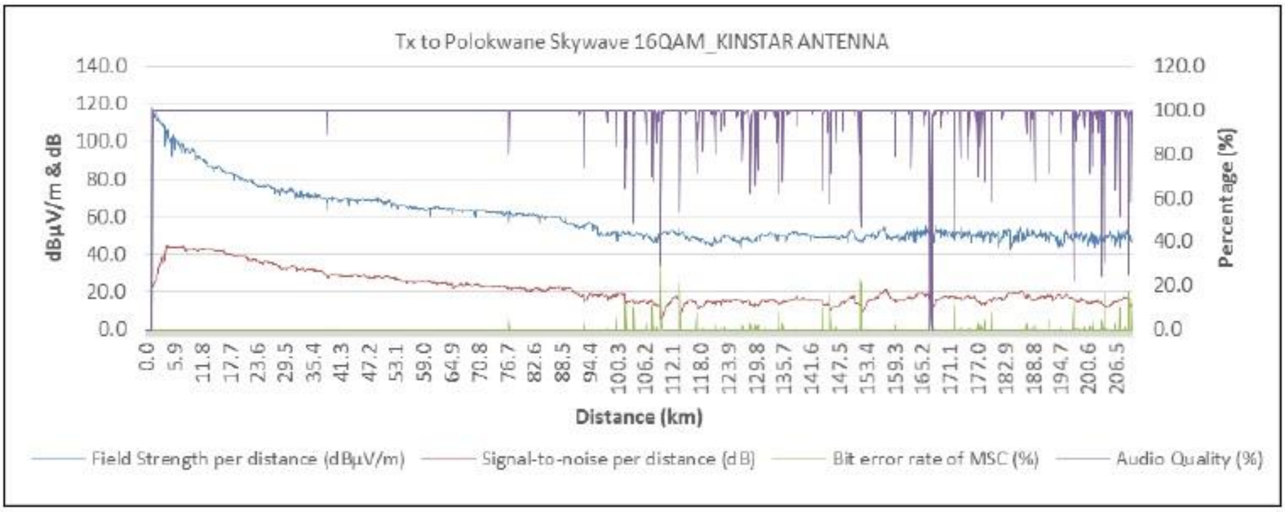
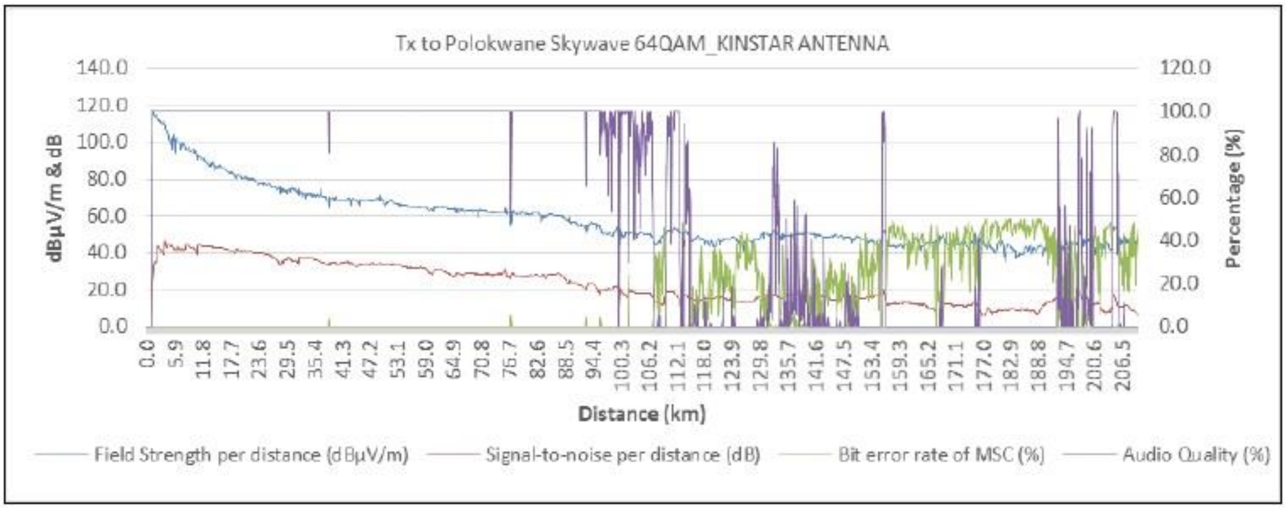



FIGURE 91

**KinStar antenna north radial route – 64QAM**



# APPENDIX E

FIGURE 92

**KinStar antenna north radial route – AM Analogue**

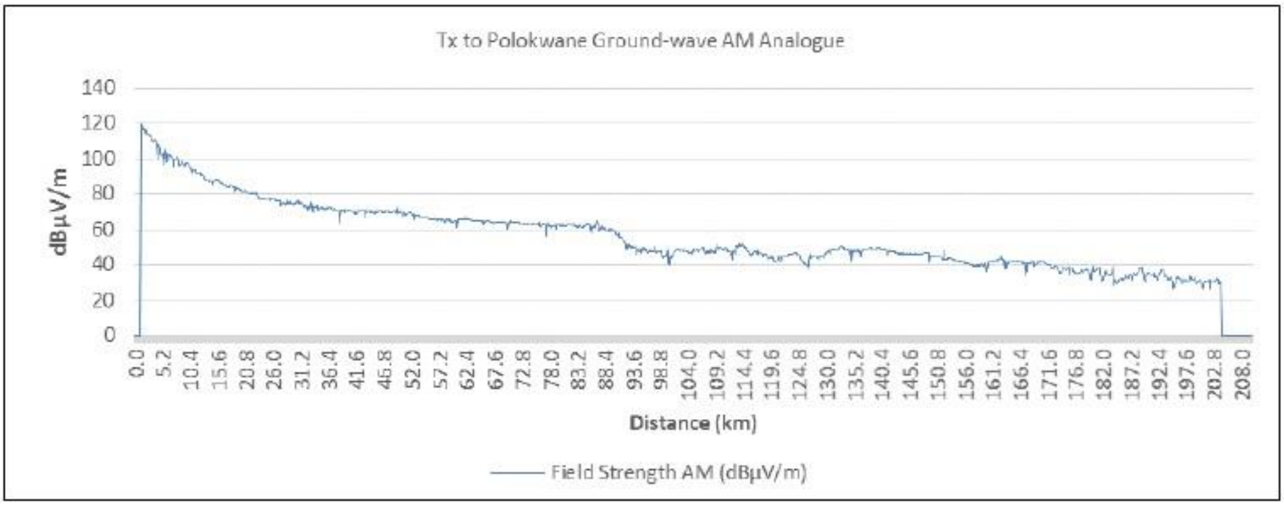
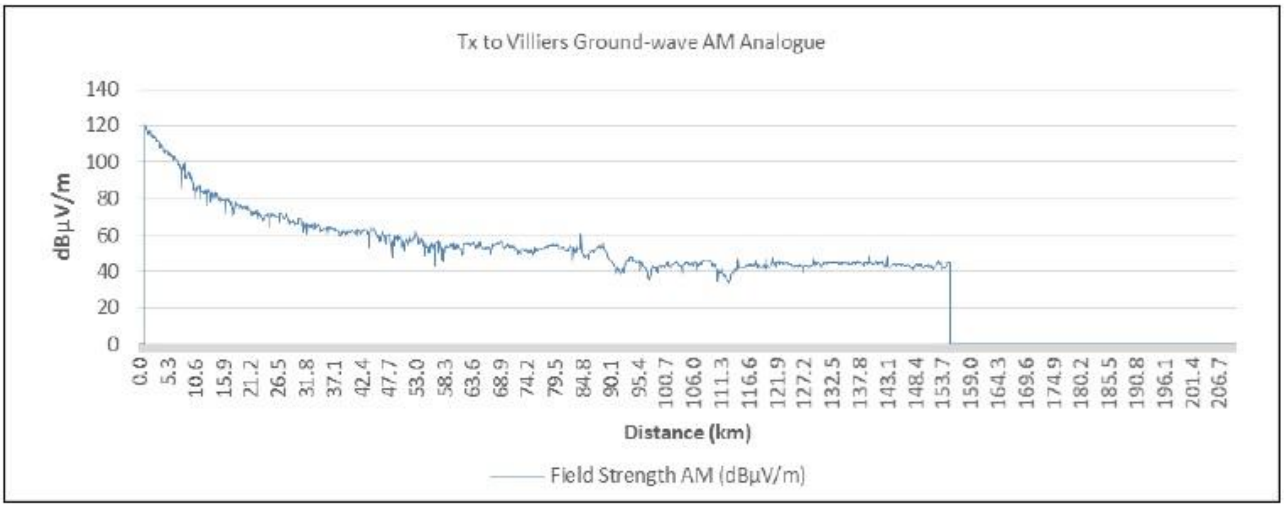



FIGURE 93

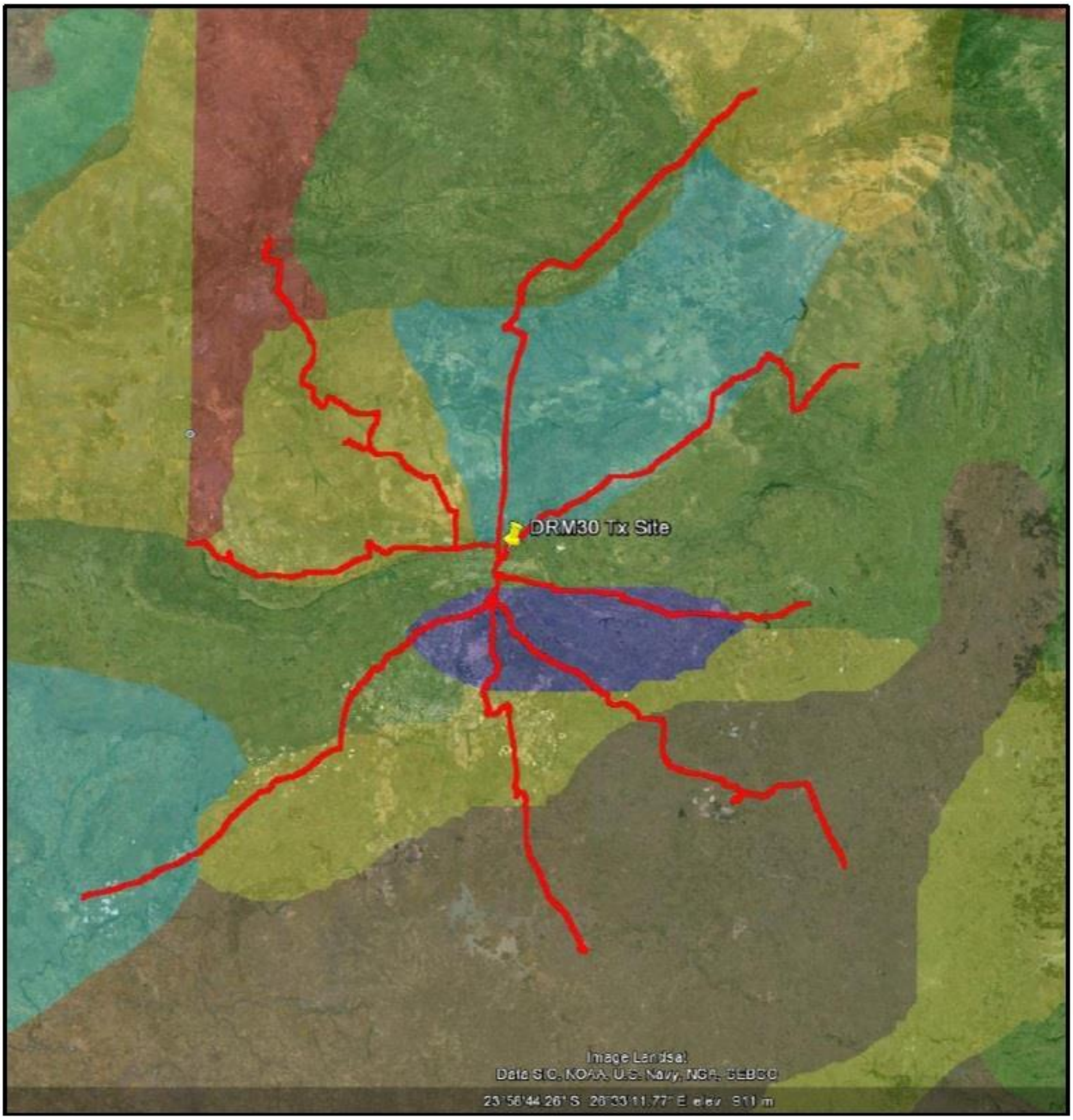
**KinStar antenna south radial route – AM Analogue**



# APPENDIX F

FIGURE 94

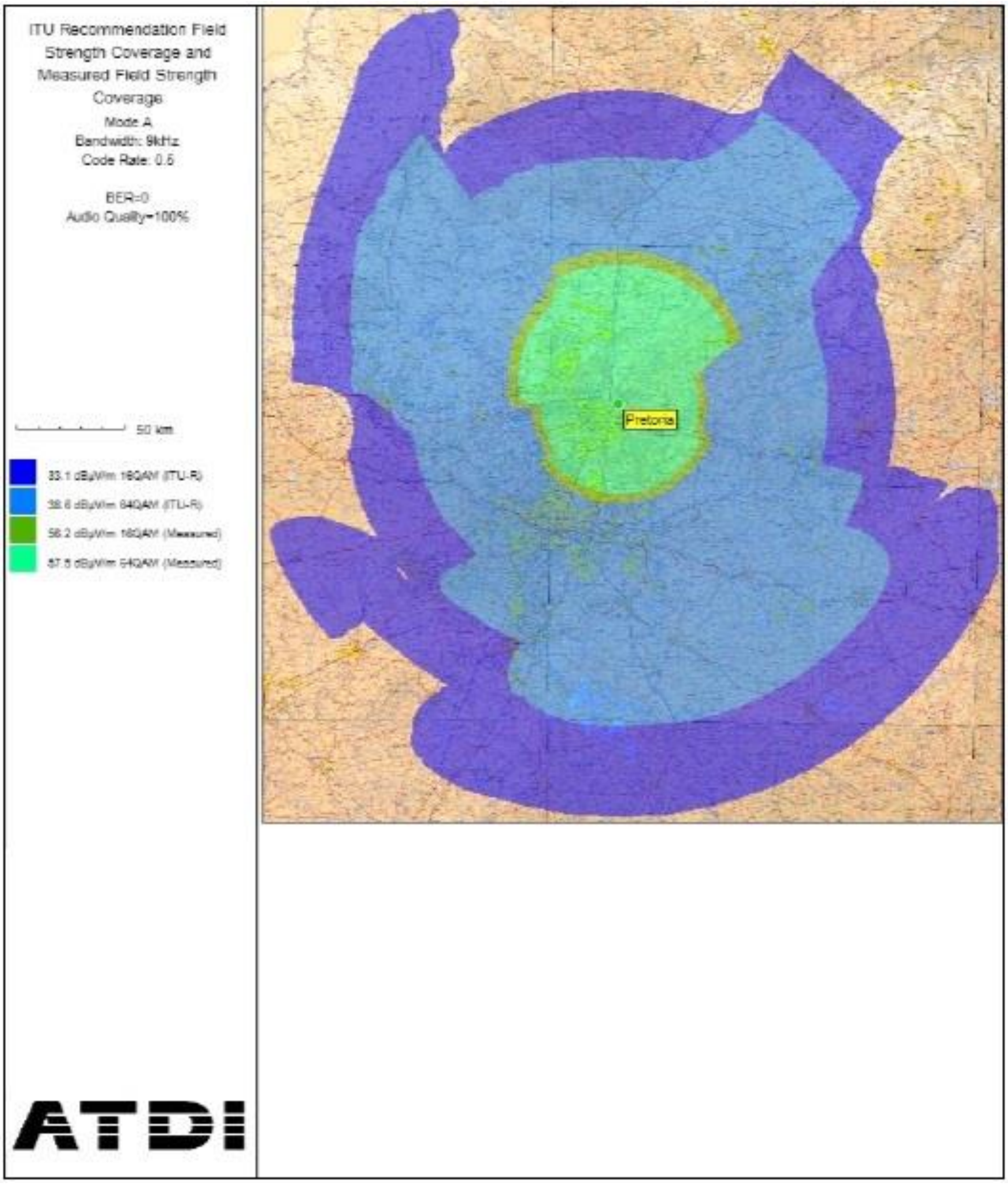
**Eight radial routes and conductivity layer**



# APPENDIX G

FIGURE 95

**DRM30 ITU Recommendation Field Strength Coverage and Measured Field Strength Coverage**



ATTACHMENT 2
TO ANNEX 1

## Spectrum management and service planning considerations for implementing the DRM+ system in the VHF broadcasting bands

# 1 DRM+ system characteristics

…

### 2.2.2 Band II coverage considerations

In addition to the theoretical considerations above, recent case studies on the implementation of DRM+ in Band II (see EBU Report TECH 3357[13]) have assessed how the DRM+ standard could be introduced into Band II either to replace existing FM transmissions or to provide new services. These studies confirm that DRM+ can provide the same coverage, more economically than an FM broadcasting station, by using much lower power levels. Some technical compatibility problems with low level digital artefacts remain to be resolved where FM and DRM+ transmissions would continue to serve overlapping areas. The mechanism involved is not entirely clear at present; and the disturbance is not consistently observed, becoming less apparent where the band is heavily occupied. In any event, the problem would disappear after a complete transition to DRM+ in Band II.

A prime consideration when implementing DSB is to recognize the how listener demand has changed since the FM broadcasting was introduced, when planning was based on fixed reception using an external 10m high antenna, towards a more comprehensive planning objective based on achieving stable high quality mobile reception, particularly in vehicles.

Attachment 2.1 provides coverage and quality assessments of the performance of a low power DRM+ VHF broadcasting station established in an urban area of Rome, characterized by a very congested FM environment. These assessments provide further information on optimizing mobile reception of DRM+ transmissions, notably that:

– acceptable stereo coverage in mobile reception conditions is achievable where the predicted field strength is comparable with 44 dBμV/m and interference is negligible;

– the most robust coding scheme configuration for DRM+ can provide stereo programme coverage better than is achievable with FM along with better subjective listening experience.

Attachment 2.2 provides coverage and quality assessments of the performance of an FM and DRM+ simulcast broadcasting station in Batam City, Indonesia. The key findings of this trial are that:

– a wider DRM+ coverage area is achieved than the with FM even though the DRM+ transmitted power was only about 10% of the FM transmitter power,

– no disturbance caused to the upper and lower adjacent FM channels;

– indoor and mobile reception quality of DRM+ is good.

Another factor, which many broadcasters may consider to be significant when deciding make the transition from existing analogue FM services to digital technology and in choosing which digital technology to use, are the practical considerations involved, such as:

---

[13] See http://tech.ebu.ch/docs/tech/tech3357.pdf.

– the ability to re–use the existing transmission infrastructure and make the transition on a per service area basis;
– avoid changes to the service area that would inconvenience the existing listener base.
– In these respects the findings reported in Attachments 2.1 and 2.2 also show that a transition to DRM+ would have the following merits:
– the existing transmitting antenna system can be re–used without any particular precautions, apart from the usual need not exceed the maximum peak envelope power of the digital signal;
– the original service area can be preserved when re–using the existing antennas; which means that there is no disruption or loss of service to listeners – a consideration that particularly beneficial to local broadcasters who have to target specific service area;
– the possibility to use SFN techniques, which regional broadcasters may advantageous in those situations where frequency re–use can help in optimizing regional coverage.

## 3 Conclusions

Planning of DRM+ services in Band II would generally tend to start from the same 100 kHz grid as conventional FM service in Europe or the 200 kHz grid commonly used in Regions 2 and 3. This would certainly provide for more efficient use of the available spectrum, especially as the analogue services are switched off. However, there is scope for further flexibility in planning DRM+ services in that the specification allows for DRM+ signals to be located at any frequency which is a multiple of 10 kHz. This would allow a DRM+ service to be placed close to an FM emission as part of a transitional arrangement (see Figures 43 and 44 of Recommendation ITU–R BS.1114–7) or use of the double DRM+ configuration shown in Figure 2.

The analysis above shows that DRM+ can provide broadcast coverage comparable to FM broadcasting at much lower power levels – some 40 dB lower if retaining the fixed receive/external antenna configuration. But more practically, a power reduction of 10 to 15 dB on the required minimum field strength for FM reception would, without other interference constraints, ensure satisfactory coverage for portable/mobile reception. The lower transmission powers possible with DRM+ should also prove advantageous when considering compatibility with aeronautical services operating in the adjacent bands above 108 MHz.

DRM+ can also provide high quality broadcasting services in Band I and III, where these are not already used for TV or DAB.

However, the absence of a wide variety of low cost sets capable to receive DRM+ signals in the VHF broadcasting bands represents a problem.

…

*[Editorial note: Re-located Attachments 2.1 and 2.1bis as Attachments 1.1 and 1.2 as shown above.]*

ATTACHMENT 2.1
TO ANNEX 1

# Field trials in Rome on the possible use of the DRM+ system in VHF Band II to migrate from FM sound broadcasting to digital technology

## 1 Introduction

In December 2011 Vatican Radio carried out some broadcasting tests of DRM+[14] in the VHF Band II at 103.8 MHz. The aim of the tests was to verify the performance of DRM+ in a difficult interference scenario such as the FM VHF band II in Rome and to check the compatibility of the digital technology with existing antenna arrays having complex RF coupling systems such as the one located in the Vatican.

The frequency used was assigned to the Vatican in the GE84 Agreement and was chosen for two main reasons: it is not used during a few timeslots in the morning and it suffers from some strong interferences coming from stations operating at 103.7 MHz and 104.00 MHz located close to Rome (some of those interfering stations in some points within the 103.8 MHz FM service area do not comply with the protection ratios specified in Recommendation ITU–R BS.412.9[15]).

The tests were carried out taking into account the normal programs schedule. During the tests the digital transmitter was connected to the antenna feeder via a changeover, leaving the analogue transmitter in stand–by. The antenna array is a complex system: four FM transmitters at different power levels share the same antenna with elliptical polarization and omni–directional horizontal radiation pattern.

This contribution details the results of the test and some relevant considerations.

## 2 Description of the installation

A low power transmitter was installed in the transmitting building entitled to Pope Leone XIII [N41°54’13.83” E12°27’0.11”] located in the Vatican City (Fig. 22). The position has been identified as CVA in all the maps in this document.

[14] Defined as System G in Recommendation ITU-R BS.1114.

[15] For further information see Fig. 1 of Recommendation ITU-R BS.412-9.

FIGURE 22

**FM station in the Vatican**

FIGURE 23

**DRM+ Transmitter**

The DRM+ transmitter was composed by a linear power amplifier NAUTEL model VS1 300W RMS with the corresponding exciter and a digital modulator RFmondiale model LV6M (Fig. 23). The modulator was fed with a DRM+ multiplex generated by a Fraunhofer DRM Content Server R5 operating in the Transmitting Centre of Santa Maria di Galeria located about 20 km outside Rome. The DRM+ multiplex was sent to the transmitter via a private Ethernet network link. The test was carried out at 200 W RMS complying with the DRM+ transmitter spectrum mask.

FIGURE 24

**Particular of one transmitting element**

The power, frequency, channel bandwidth and multiplex characteristics are given in the tables below:

TABLE 12

**DRM Channel description; content server configuration**

| | |
|---|---|
| Frequency | 103.8 MHz |
| Power | 200 W RMS |
| Antenna | 10 bays |
| Antenna hor. beam | Omni |
| Polarization | Elliptical |
| Gain (vert. comp.) | 8.18 dBd |
| Gain (hor. Comp.) | 7.44 dBd |
| Power split. (V/H) | 0.70/0.30 |
| Channel bandwidth | 100 kHz |

TABLE 13

**Configured services on the DRM Multiplex**

| | |
|---|---|
| DRM channel BW | 100 kHz |
| MUX ref. ID | Test DRM+ |
| Timeslot. (UTC) | 800–1 200 |
| Robustness | MODE E |
| Channel BW | 100 kHz |
| MSC | 4QAM |
| Protection level | EEP PL=0 [0.25] |
| SDC | 4QAM |
| Max net bit rate | 37 200 bps |
| Unused bit rate | 0 bps |

TABLE 14

| | |
|---|---|
| Service identification | Vatican DRM+ |
| Audio codec | AAC[16] |
| Audio mode | Full Stereo |
| SBR | ON |
| Sampling rate | 24 kHz |
| Audio bitrate | 36 880 bps |
| AFS | NO |
| Text message | 320 bps |

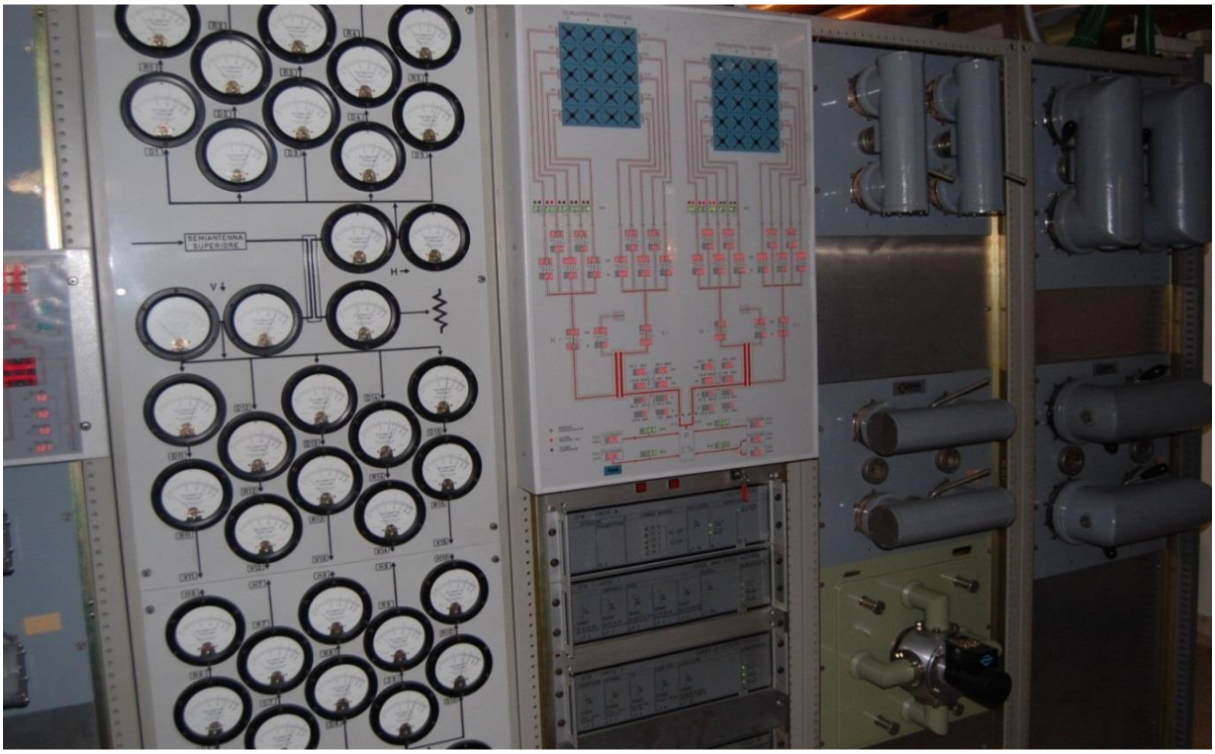
The antenna was manufactured by “SIRA ANTENNE” in the nineties. Each bay is composed of four 2×3 elements crossed YAGI installed on the external sides of the square–section mast.
A complex RF routing system composed of combiners, filter cavities and directional couplers permits proper insulation among all the transmitters and adequate power splitting for polarization diversity.

Four different FM transmitters are normally operating on 93.3 MHz, 96.3 MHz, 103.8 MHz and 105 MHz at different power levels. The antenna feeding system permitted to disconnect the analogue transmitter operating at 103.8 MHz and connect the digital one. The analogue transmitter was switched off during the tests. The tuning of the RF routing system was not modified to optimize the signal transfer from the transmitter to the antenna.

16 AAC, Advanced Audio Coding.

FIGURE 25

**Antenna control panel**

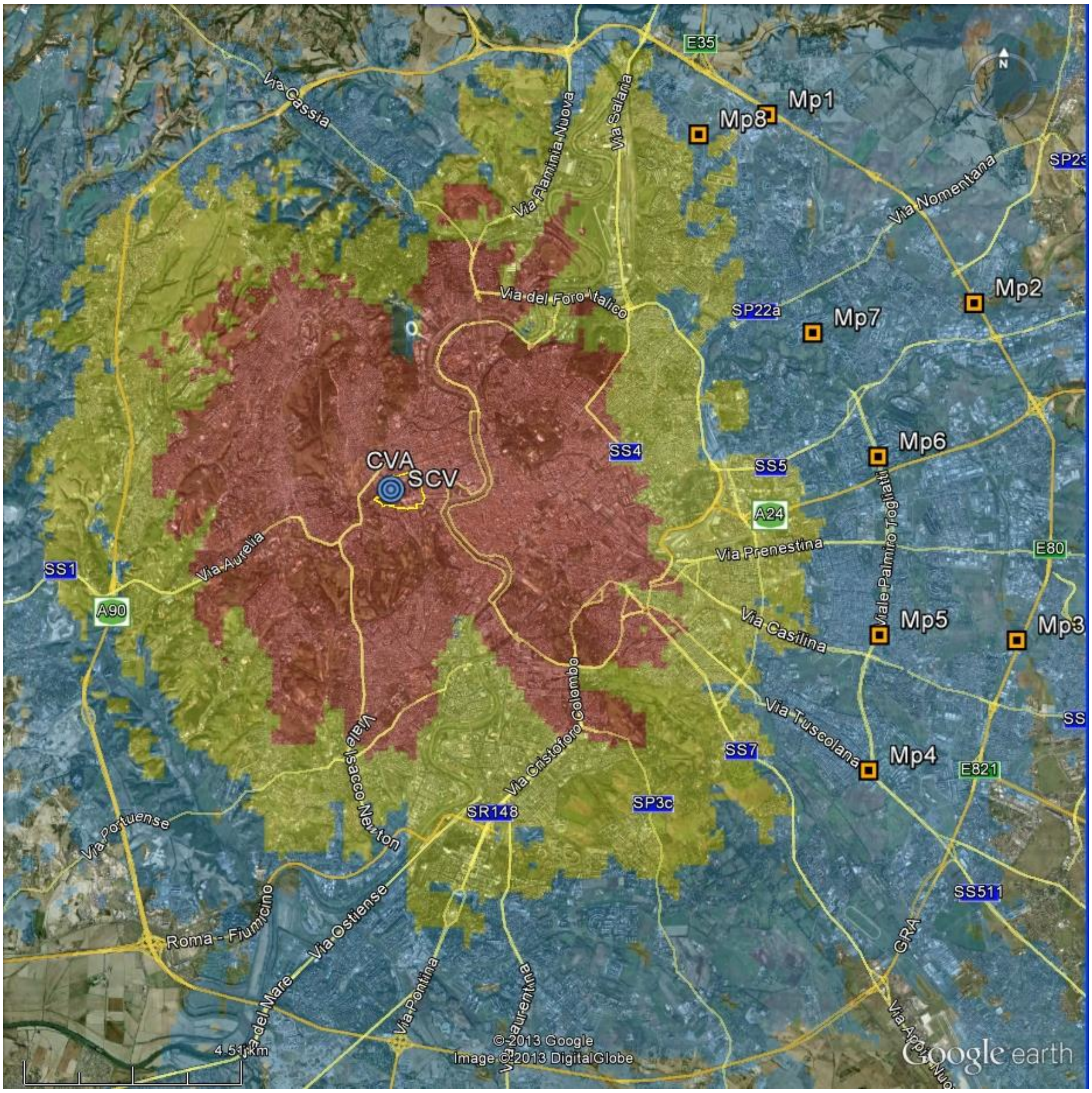


## 3 The existing FM service

The 103.8 MHz analogue FM service is currently operated at 9 kW; Map 1 shows the prediction of the field strength vertical component 10m above the ground. Due to the congestion of the FM band in Rome the effective service area for portable reception could be considered unconditioned only in the area identified in yellow or red; in other areas (in cyan) the coverage depends on the particular reception condition (indoor/outdoor, fixed/mobile/portable), in those areas the listening experience is quite poor due to splats coming from interfering stations operating from transmitting locations higher than the Vatican. The interference scenario has been monitored in 8 different points indicated as Mp1…Mp8 on the map below. The closer interferer is a station operating with a low power transmitter at 103.7 MHz from Vermicino, located 20 km from the Vatican in the SE direction. Another interferer operating at low power on 103.9 MHz is located over Tivoli (in the E direction) and another one operating at high power at 104 MHz is located in the SE direction, having Rome as target service area.

MAP 1

**The current analogue FM service**




Colour legend of Map 1:

| | | |
|---|---|---|
| ■ (red) | ■ (yellow) | ■ (blue) |
| EM > 90 dBμV/m | EM > 82 dBμV/m | EM > 74 dBμV/m |

Table 15 shows the signal strength ratios measured in the monitoring points considered:

TABLE 15

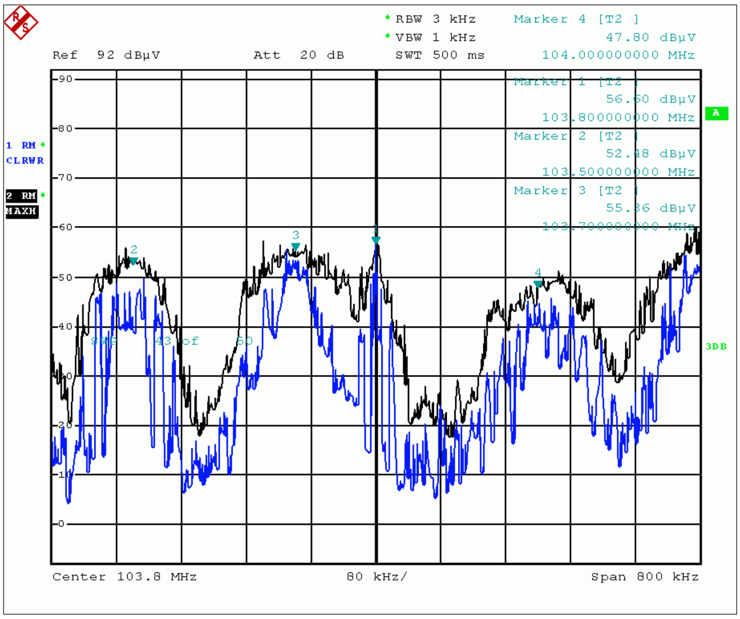
| | **103.8 MHz** | **103.5 MHz** | **103.7 MHz** | **104.0 MHz** |
|---|---|---|---|---|
| | **dBµV** | **Int.–Ref.<br>dB** | **Int.–Ref.<br>dB** | **Int.–Ref.<br>dB** |
| Mp1 | 55.8 | 3.5 | –9.5 | 6.4 |
| Mp2 | 58 | 15.2 | –12.2 | 11.9 |
| Mp3 | 63 | 15.3 | –2.8 | 11.3 |
| Mp4 | 59.8 | 14.6 | –11.2 | 7.1 |
| Mp5 | 53.8 | –5.3 | –10.3 | 0.9 |
| Mp6 | 56.6 | –4.1 | –0.7 | –8.8 |
| Mp6 | 61.7 | –1.2 | –14.8 | 1 |
| Mp8 | 63.9 | –2 | –16.1 | –7.4 |

The first column shows the RF voltages measured at the receiver in dBµV of the reference signal at 103.8 MHz. The other columns display the difference between the interfering signal and the reference one.

The relative protection ratio as given in Recommendation ITU–R BS.412–9 is satisfied only in few points[17]. Figure 26 displays, as example, the interference scenario measured in Mp6.

FIGURE 26

**Spectrum plot taken in Mp6**




[17] See Fig. 1 of Recommendation ITU-R BS.412-9, case stereophonic broadcasting steady interference.

# 4 The tests and the results

The measurements were performed by Vatican Radio using the following equipment:

– RF Mondiale DRM+ Test Receiver connected to GPS.

– Log File containing all necessary data such as geographical, electromagnetic and audio errors, with one record for each DRM Frame.

– Kathrein stilo antenna (model 510351), physical length 79 cm measured according to the manual.

– Rhode Schwarz ESPI Test Receiver.

– Fiat "Scudo" minivan with antennas, DC power system and on–board inverter.

– An ad hoc ground plane was realized on the car roof.

The "Centro Nazionale Controllo Emissioni Radioelettriche Roma" department of Italian "Ministero dello Sviluppo Economico", attended one day session of measurements.

FIGURE 27

**Measurement vehicle**

The monitoring sessions examined the mobile reception of the 103.8 MHz signal on different paths likely to represent the reception of the signal in the main target area. The results are detailed below.

Map 2 shows audio reception along three different paths representative of Rome:

a) the main centre;

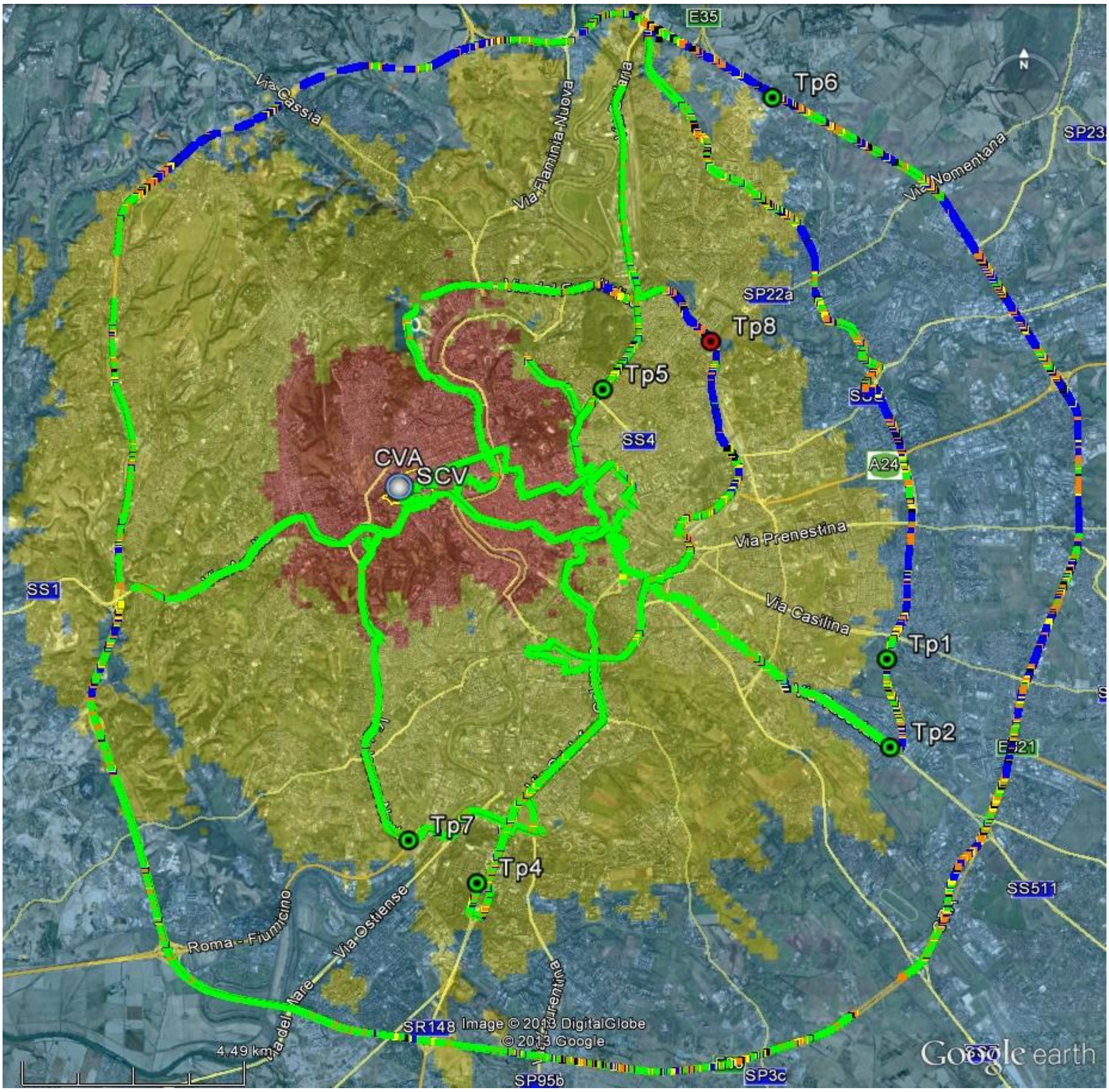
b) a ring surrounding the main centre;

c) the "GRA" motorway (motorway A90/E80) encompassing the main urban area (about 10 km radius).

According to Recommendation ITU–R BS.1660–6 the minimum median field strength for 4QAM modulation scheme R = 1/3 is 40.7 dBμV/m for portable outdoor reception and 42.3 dBμV/m for mobile reception.

MAP 2

**Measured DRM+ reception along three different paths representative of Rome**



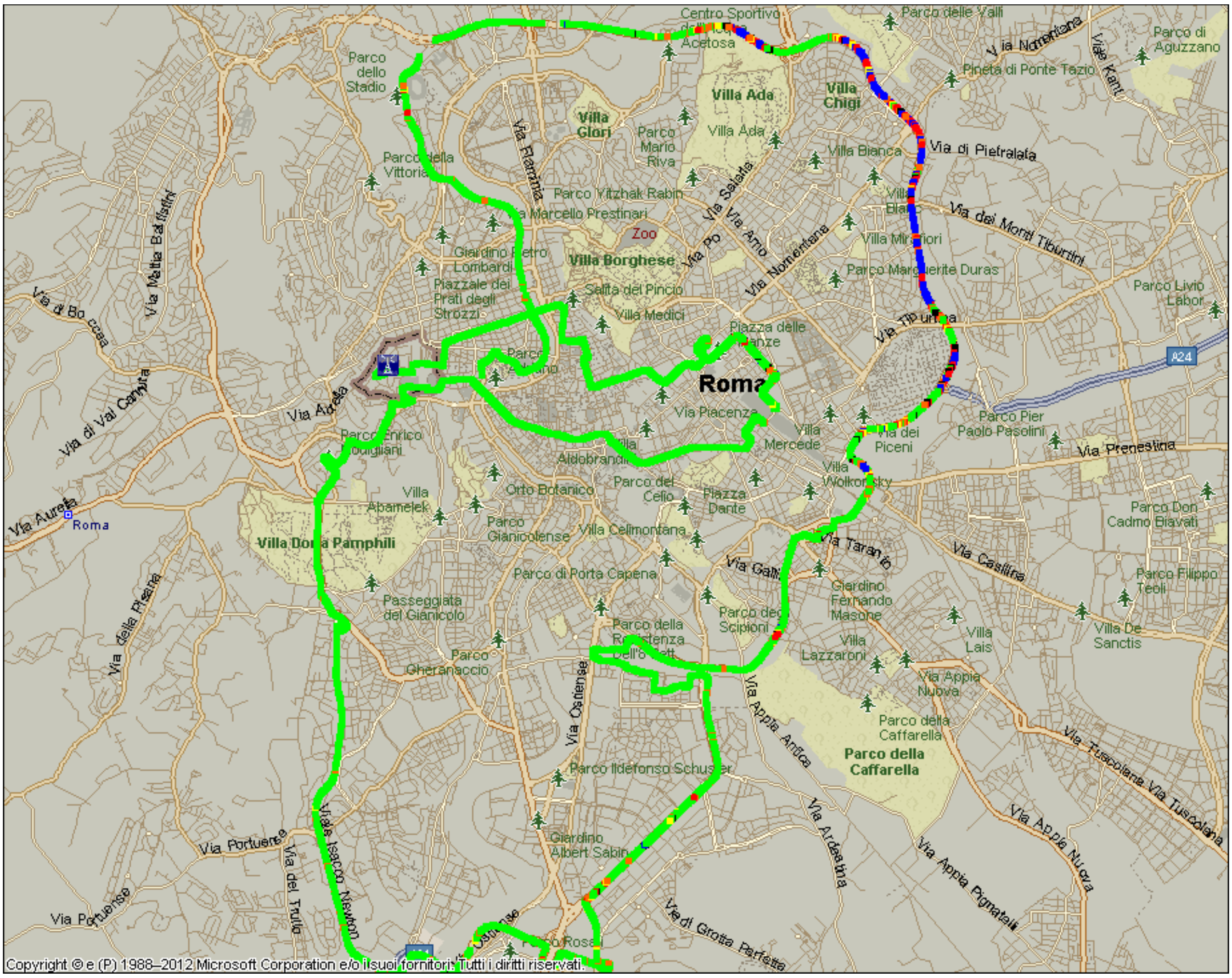

<table>
<tr><td colspan="6">Thresholds related to the DRM decoding process (paths):</td></tr>
<tr><td>■ Receiver status undefined[18]</td><td>■ No Sync</td><td>■ Sync ok</td><td>■ FAC ok</td><td>■ SDC ok</td><td>■ Audio OK</td></tr>
<tr><td colspan="6">Thresholds for predicted field strength at 10m (overlaid):</td></tr>
<tr><td colspan="2">■ EM > 84 dBμV/m</td><td colspan="2">■ EM > 64 dBμV/m</td><td colspan="2">■ EM > 44 dBμV/m</td></tr>
</table>

[18] This status is representative of a transition condition of the receiver. In this situation is not possible to determine *a priori* if audio was decoded or not. In all statistical analysis of the audio decoding process in this situation audio has been considered as NOT decoded.

Map 3 shows the measured DRM+ reception in two paths representing the main centre of Rome. The legend of colours with respect of the DRM+ decoding process is the same as the one of Map 2.

MAP 3

**Measured DRM+ reception in two paths representing the main centre of Rome**




It has been possible to decode the audio signal in 98.3% of location belonging to the internal ring and 87.8% locations of the external one. These percentiles also include locations inside that should be theoretically excluded from the statistics.

It should be noted that in the north east of the external path of Map 3 there are many points marked in blue; the issue has been investigated and two reasons have been identified:

– the path passes through of a long tunnel with only some small parts open to free sky, in those points there was no propagation;

– that area is quite depressed with difficult propagation conditions.

Map 4 shows the elevation profile in one direction and Fig. 28 the EM free space prediction in the point corresponding to the red cross on Map 4.

MAP 4

**Particular of the external path with terrain elevation profile over the red line**

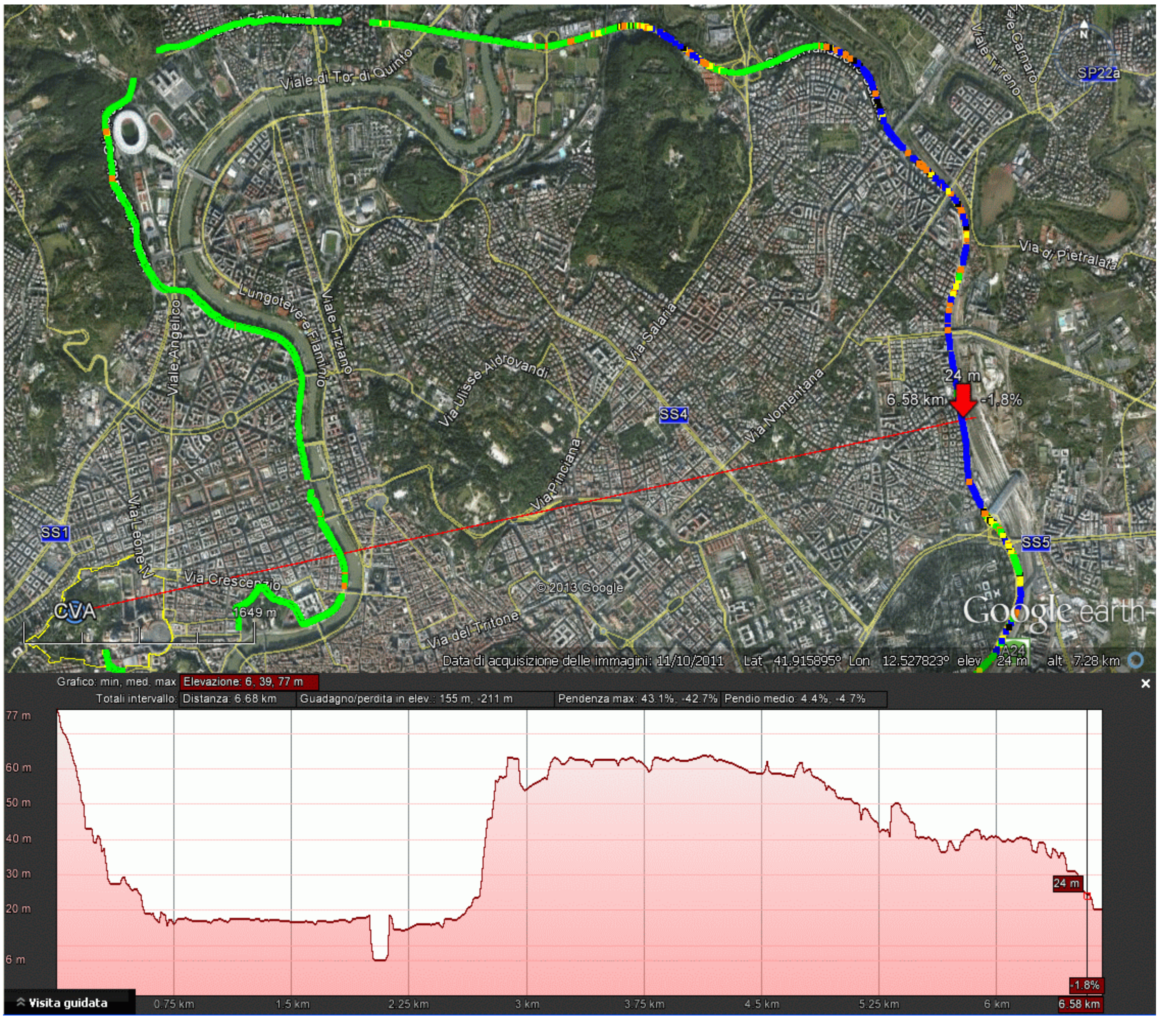
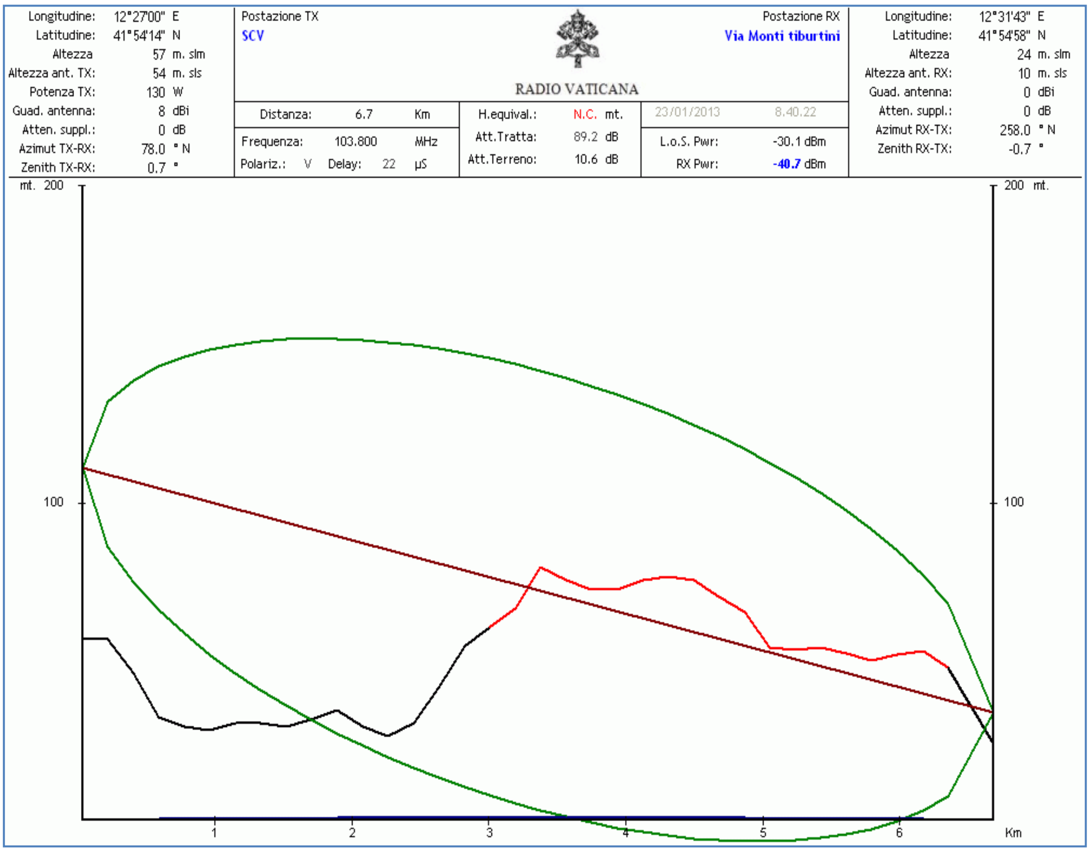
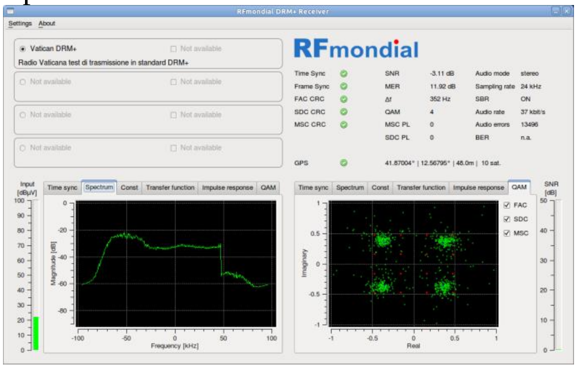


FIGURE 28

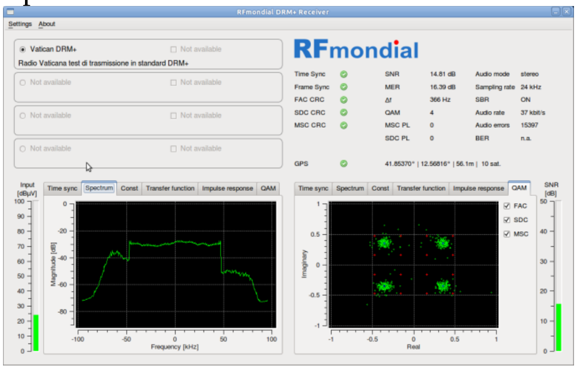



The Figures below give an idea of the interference scenario; they show screenshots of the software DRM+ receiver taken in test points Tp*1..n* in Map 1.

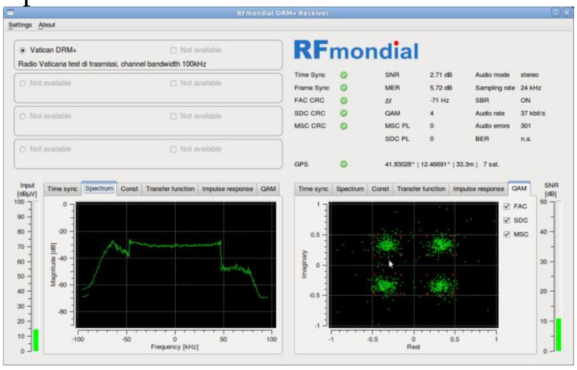
Tp1



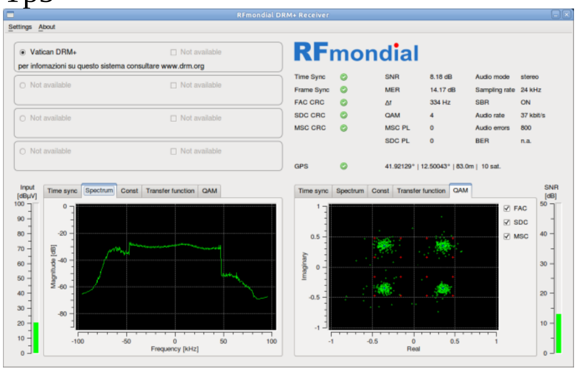

Tp2



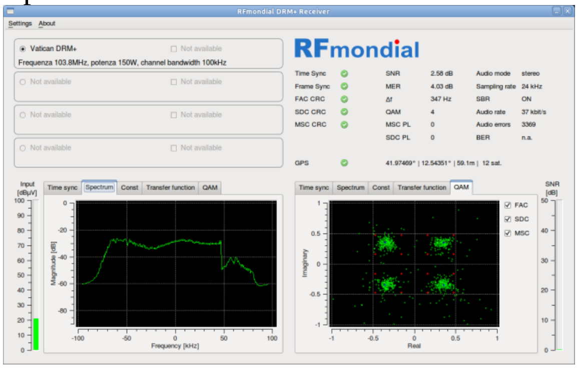

Tp4



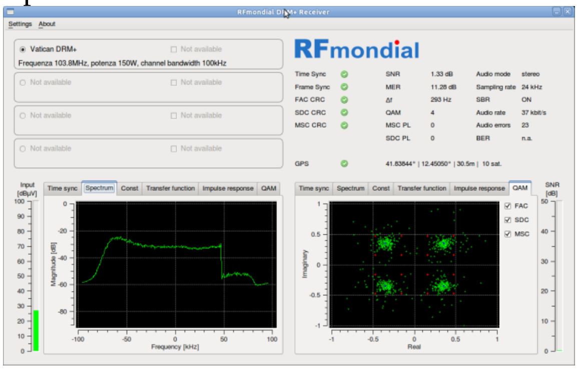

Tp5



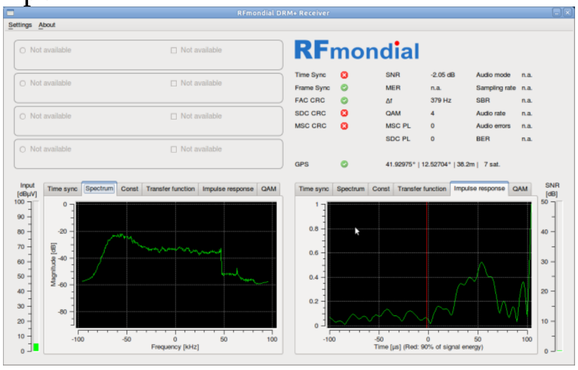

Tp6



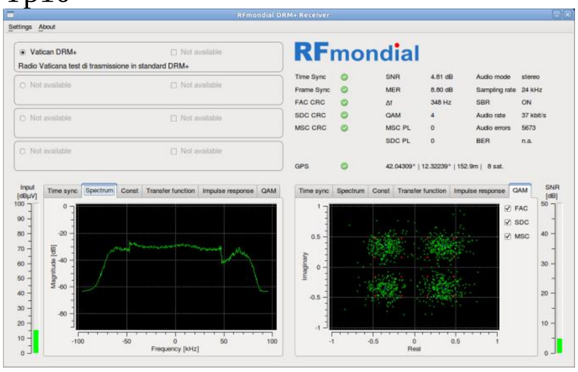

Tp7




Tp8

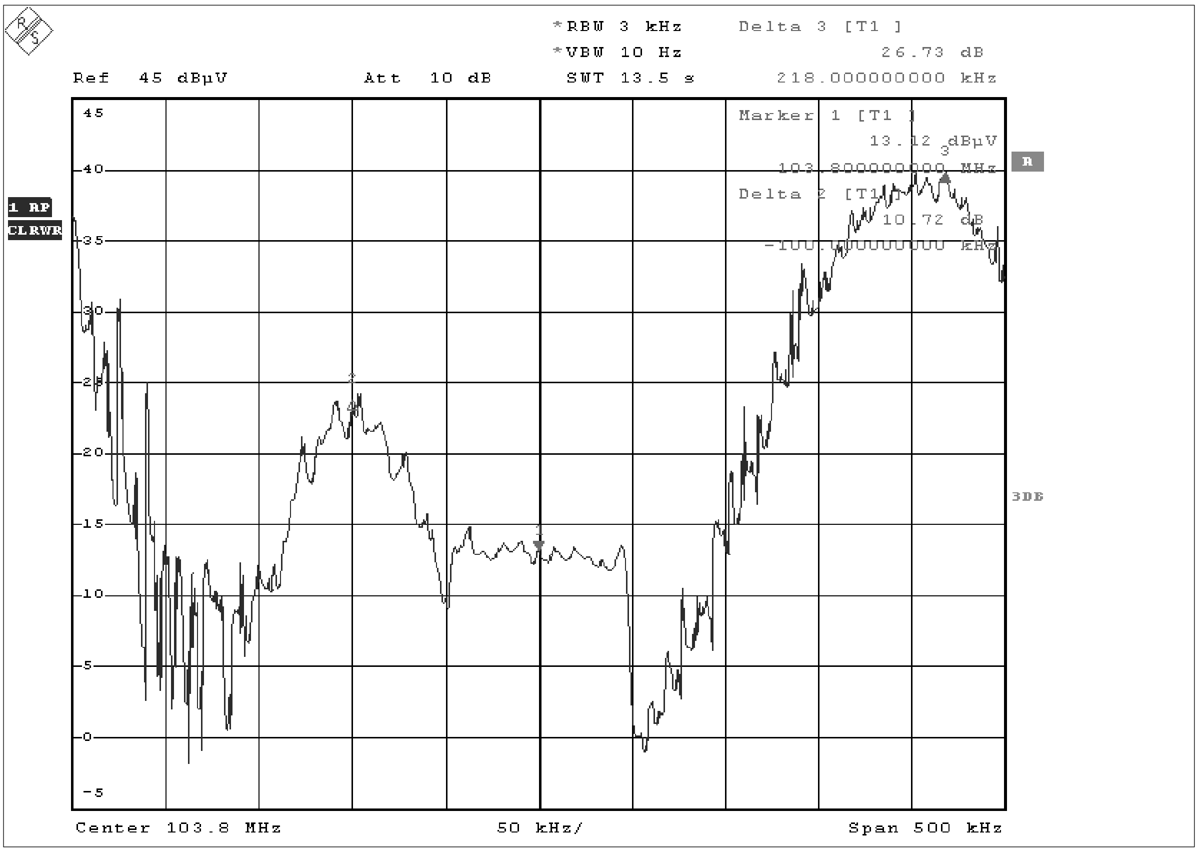



Tp10



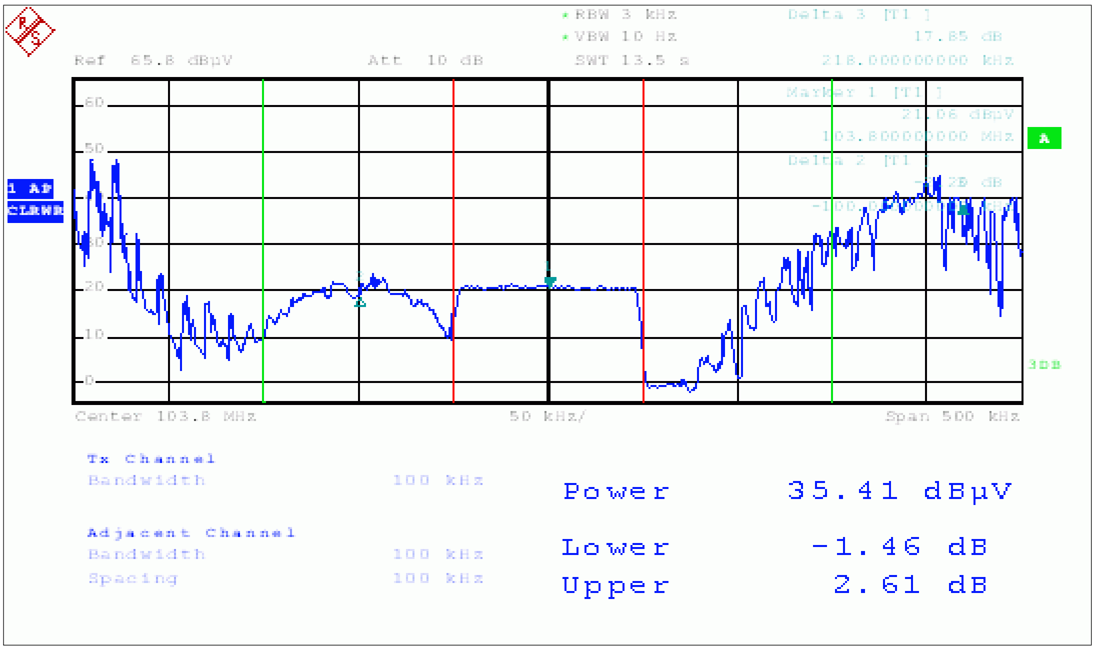
Spectrum plot of the interference scenario in Tp1:

FIGURE 29



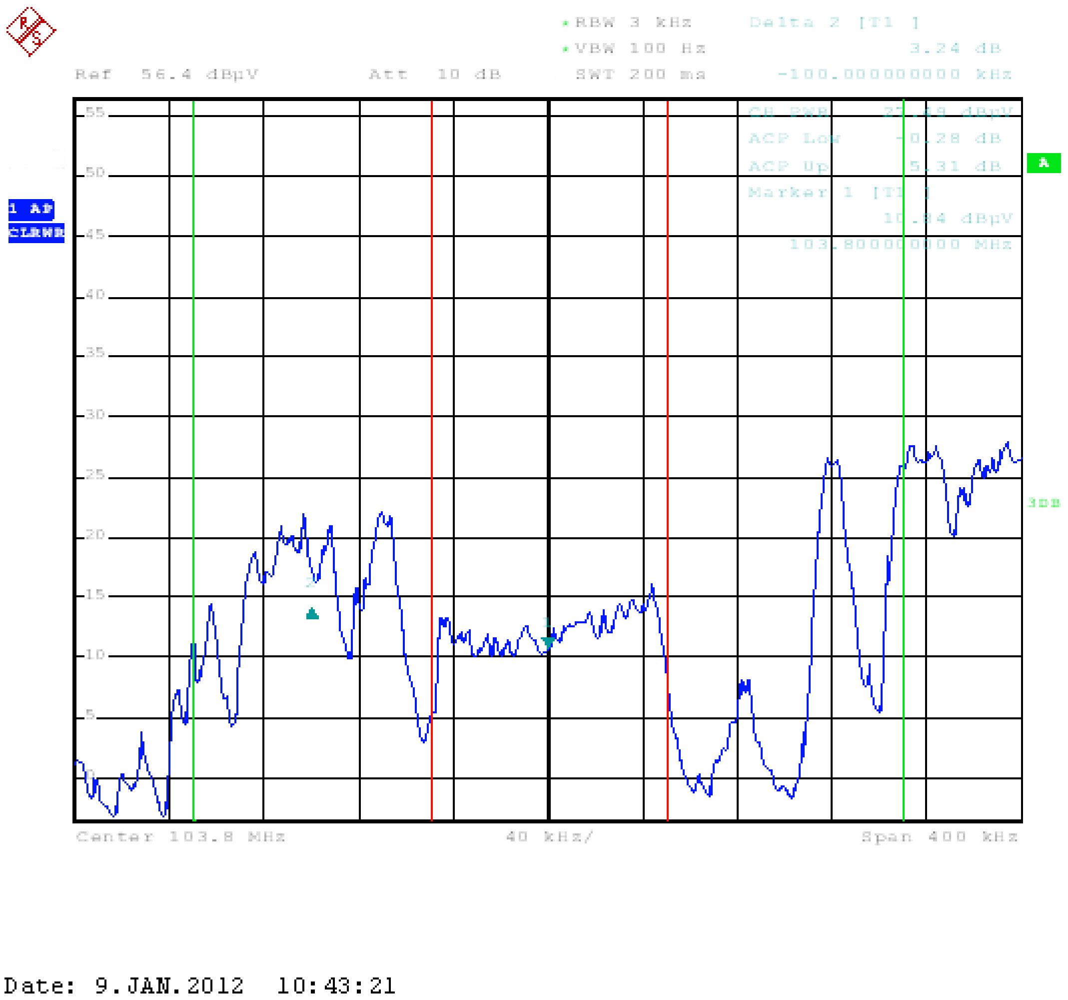

Power measurement on the interference on 103.7 MHz taken at Tp2:

FIGURE 30



Power measurements taken at Tp7 and shown as reference:

FIGURE 31




## 5 Conclusions

In respect of optimizing mobile reception, assessment of DRM+ transmissions from a low power DRM+ broadcasting transmitter located in a very congested FM environment in an urban area of Rome, shows the following main points:

– acceptable stereo coverage in mobile reception conditions has been verified in areas where predicted field strength is comparable with 44 dBµV/m and interference is negligible;

– using the most robust configuration for DRM+, it has been possible to achieve better coverage with a full stereo program than the one achieved with an analogue FM signal; the overall subjective listening experience was better than that of FM interfered with by splashes coming from adjacent stations.

In view of a possible transition of existing analogue FM services to digital technology it has been found that the use of DRM+ has the following merits:

– possibility to re–use the existing antenna system without any particular precaution, except the one relevant to the maximum peak envelope power of the digital signal;
– no modification of the target service area as a consequence of re–using the existing antennas; this means that the original “shape” of the target service area remains unmodified with benefits for those local broadcasters that have their main audience in a specific service area;
– possibility to use SFN techniques, with the attendant benefits for regional operators who may be able to re–use the frequency to achieve regional coverage.

*[Editorial note: Added new Attachment 2.2 derived from Part 1 of Doc. 6A/306).]*

ATTACHMENT 2.2
TO ANNEX 1

**Field trials in Indonesia on implementation of DRM + broadcasting in VHF Band II by Radio Republik**

## 1 Introduction

Analogue radio broadcasting using FM frequency band 88 to 108 MHz (VHF Band II) in big cities of Indonesia is very dense with less good quality (less clear) due to overlap of transmitter signals.

In order to gain benefits and advantages from DRM + digital radio broadcasting in Band II, the Directorate of Technology and New Media Radio Republik Indonesia and DRM Consortium conducted trials of FM and DRM + simulcast broadcasting for local coverage during 16-18 May 16, 2017, at TVRI Transmission Station Batam – Riau Islands.

The objectives were to determine:

– Is the digital DRM + radio transmitter coverage equal to the FM radio transmitter's coverage?
– Is the FM radio transmitter service interrupted by the digital DRM + radio transmitter?

## 2 Condition of service area Batam:

Batam City is the largest city in Riau Islands Province, Indonesia. Batam City Region consists of Batam Island, Rempang Island and Galang Island and other small islands in the Strait of Singapore and the Malacca Strait. Batam Island, Rempang, and Galang are connected by Barelang Bridge. According to the Population and Civil Registry of Batam City, as per 2015, the population of Batam was 1 030 529 people.

Batam is a city with a very strategic location. In addition to being on international shipping lanes, the city is very close, and directly adjacent to Singapore and Malaysia. The planned city Batam is one of the fastest growing cities in Indonesia. When built in the 1970s by the Batam Authority (currently called BP Batam), the city was home to only about 6 000 residents and within 40 years of the population of Batam grew 158 times over.

The city, which is part of the province of Riau Islands, has a land area of 715 km², while the total area covers 1 575 km². Batam City has tropical climate with average daily temperatures in the range of 26 to 34°C. Batam City has a mix of hilly and flat areas, and consists of 12 sub-districts and 74 sub-districts

The three FM radio channels used by Radio Republik in Batam are:

- 105.1 MHz (Programa 1);
- 105.5 MHz (Programa 2); and
- 90.9 MHz (Programa 3).

# 3 Batam geographical picture:

FIGURE 1

**Batam Island Region and surrounding areas**

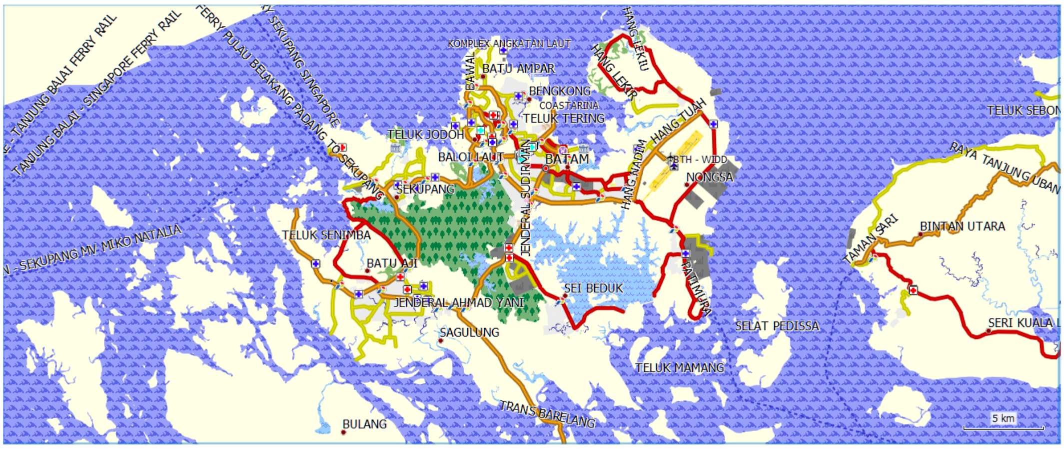



FIGURE 2

**View of hills and tall buildings**

(*Source: https://goo.gl/jf2b2h*)

FIGURE 3

**View of highly mobile environment**

(*Source: https://goo.gl/bx6oR1*)

FIGURE 4

**View of Commercial Centre**

(*Source: https://goo.gl/bVMy9X*)

FIGURE 5

**View of the Sea and Strait**

*(Source: https://goo.gl/13Q2sa)*

# 4 Description of transmitter location:

## 4.1 Location of Batam transmitter:

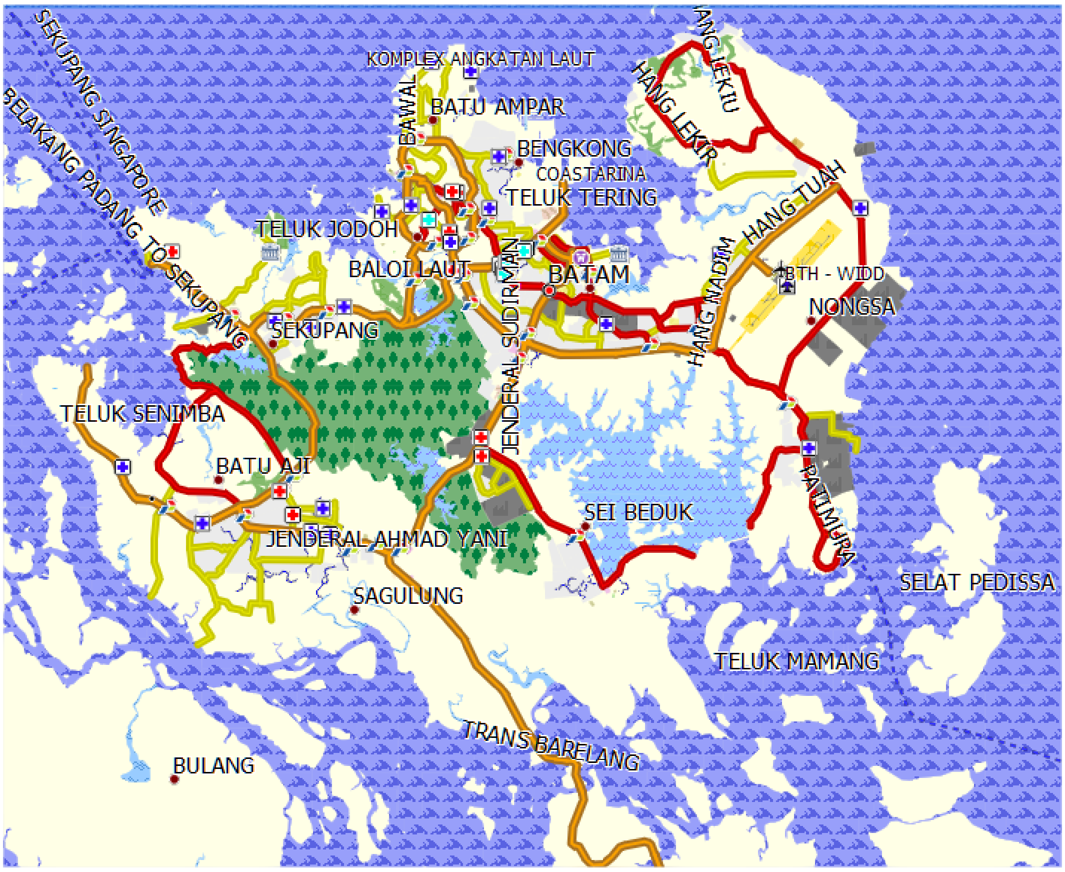
FM Transmitter RRI Batam is placed at the location *"Transmission Unit TVRI Batam"* with coordinates: 1° 07' 24.154" N; 103° 56' 44.078" E

FIGURE 6

**FM transmitter location RRI Batam (co-located Tower TVRI)**

FIGURE 7

**FM transmitter service area RRI Batam**




## 4.2 Transmitter Equipment

TABLE 1

**Transmitter Data**

| Radio Station Name | Frequency | Power | Antenna | Antenna height |
|---|---|---|---|---|
| *Pro 1* RRI Batam | 105.1 MHz | 5 000 W | 4.78 dB | 40 m |
| *Pro 2* RRI Batam | 105.5 MHz | 5 000 W | 3 dB | 40 m |
| *Pro 3* RRI Batam | 90.9 MHz | 30 W | Yagi | 30 m |

FIGURE 8

| | | |
|---|---|---|
|  |  |  Exciter stage only (TX Harris off) |
| TX Pro 1 | TX Pro 2 | TX Pro 3 |

## 4.3 Tower and antenna

FIGURE 9

| | |
|---|---|
|  |  |
| Left mast: TransTV; Middle mast: TVRI | Antenna FM 6 bay |

## 4.4 Coverage Prediction

### 4.4.1 Coverage prediction simulation:

In order to know the FM transmitter coverage of the *Pro 1* 5 kW broadcast transmitter, a simulation prediction based on technical data and existing equipment was carried out using the *Mobile Radio and Radio Coverage Prediction Application* from the website http://lrcov.crc.ca/main/index.php

The predicted FM coverage calculated this way is shown in Figures 10 through to 12.

FIGURE 10

**Coverage Prediction Simulation using Mobile Radio application for 5 kW FM transmitter**

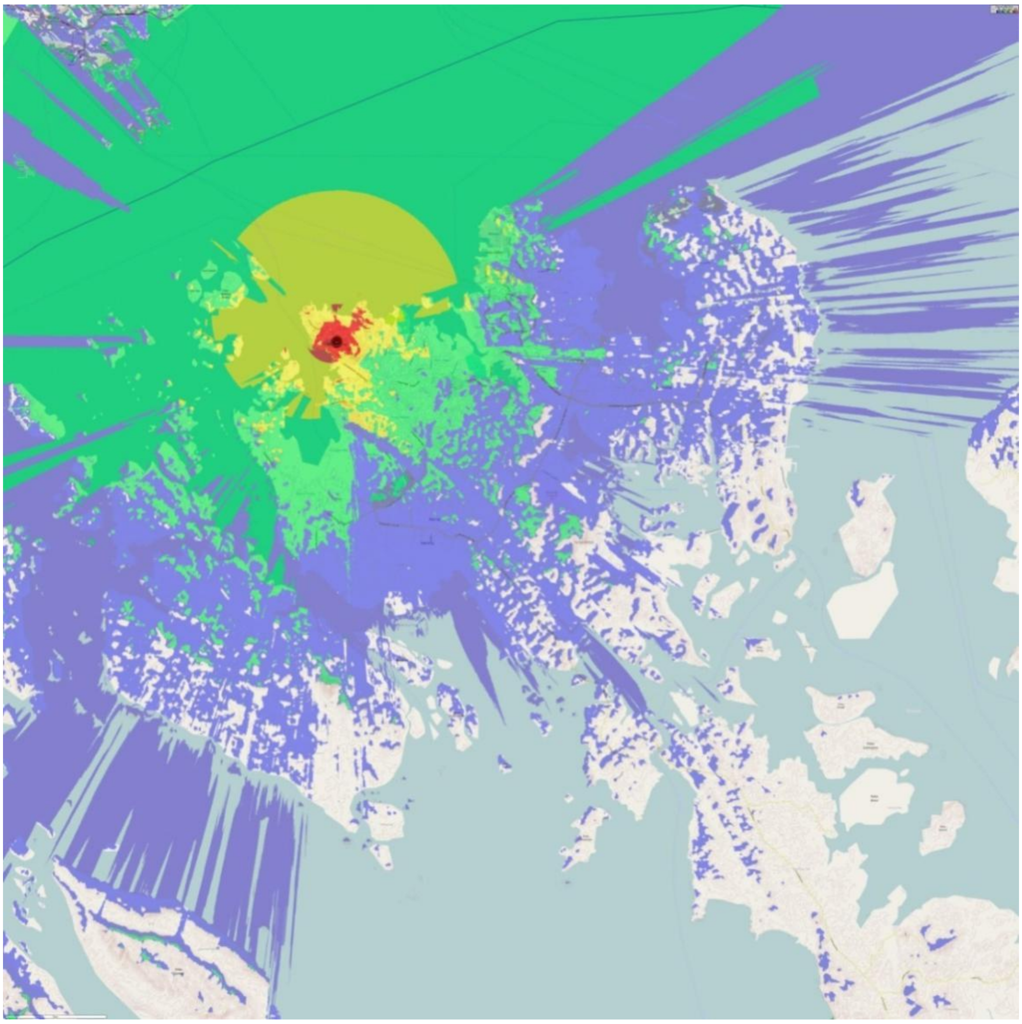


FIGURE 11

**Computer simulation overlay in Google earth**

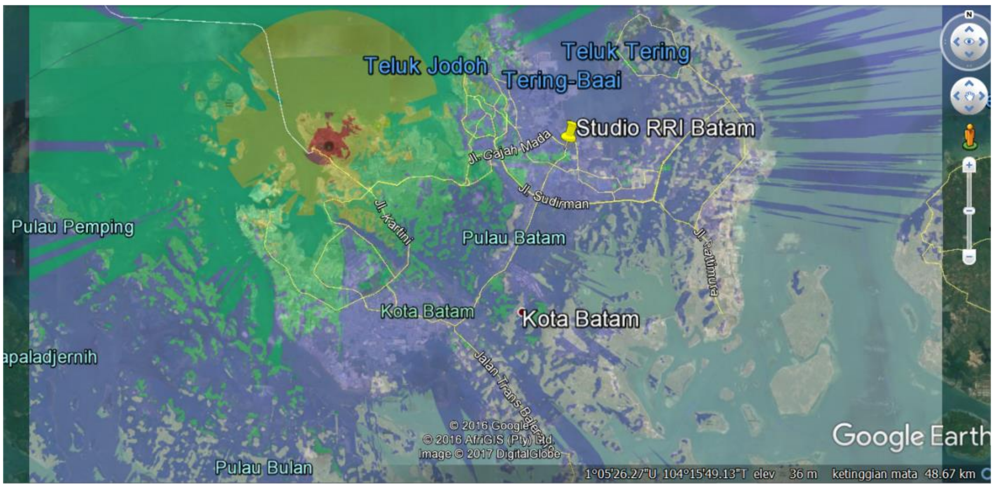
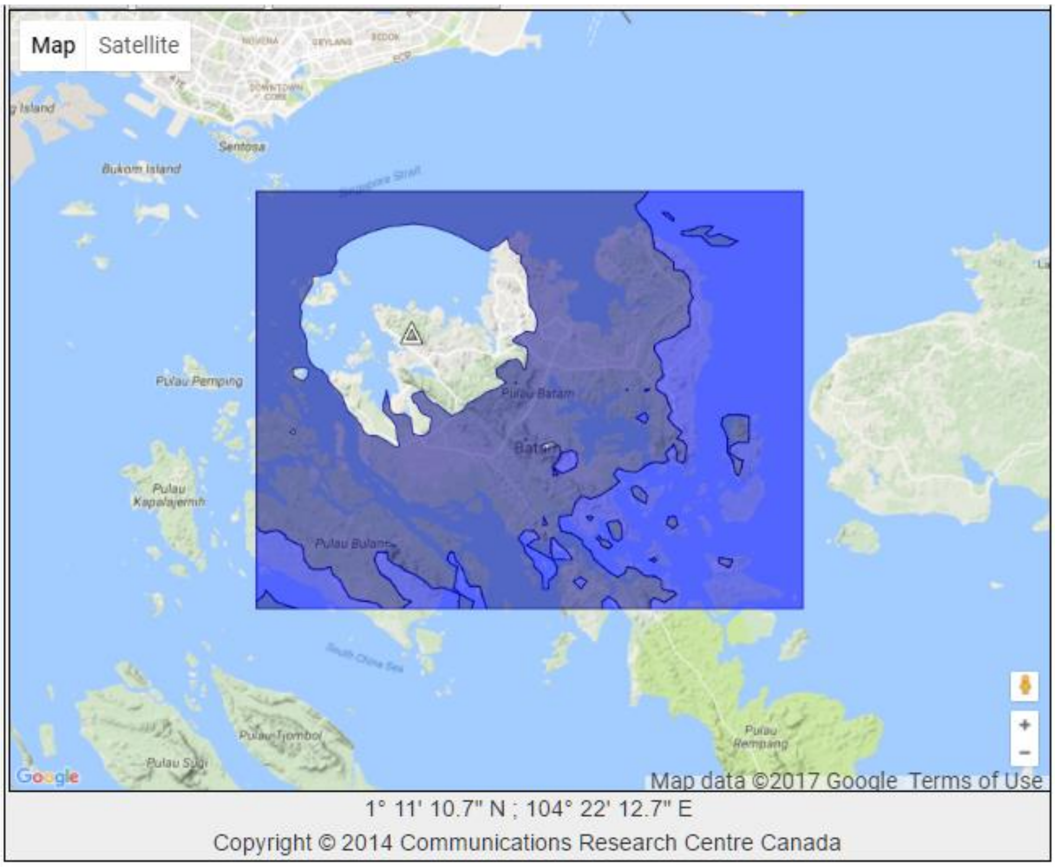


FIGURE 12

**Coverage Prediction Simulation for the 5 kW FM transmitter on larger scale map**




### 4.4.2. Digital coverage prediction simulation

In order to know the coverage of DRM + digital radio transmitters, simulation of coverage prediction was made using the *Mobile Radio and Radio Coverage Prediction Application* from the website http://lrcov.crc.ca/main/index.php The predicted DRM + coverage calculated this way is shown in Figures 13 through to 16.

FIGURE 13

**Coverage Prediction Simulation using Mobile Radio application for 200 watt DRM Transmitter**

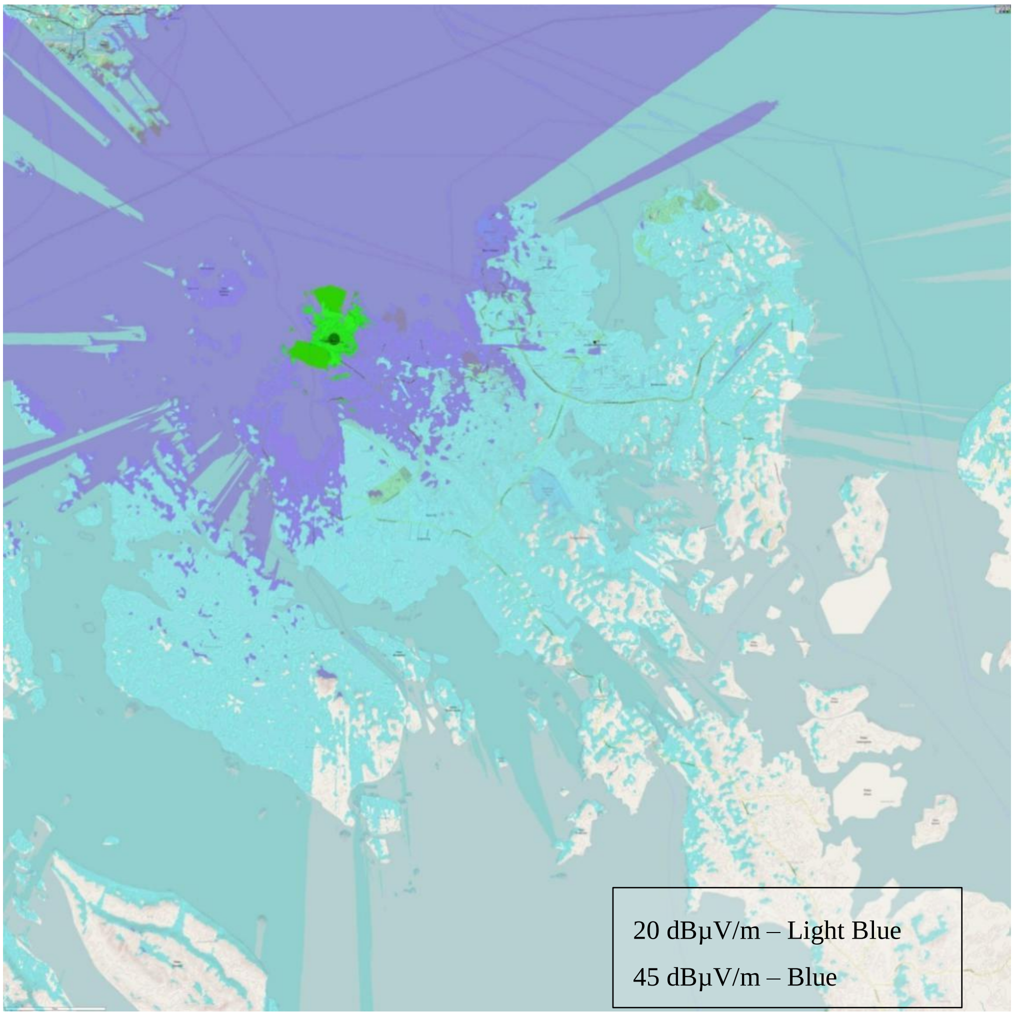



FIGURE 14

**Computer simulation overlay in Google earth**

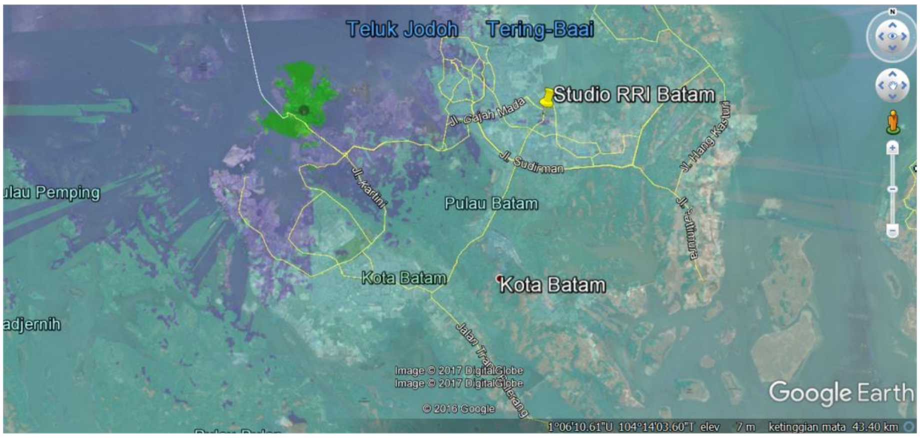


FIGURE 15

**Coverage Prediction simulation for the 200 W DRM + transmitter on larger scale map using the application from the website**

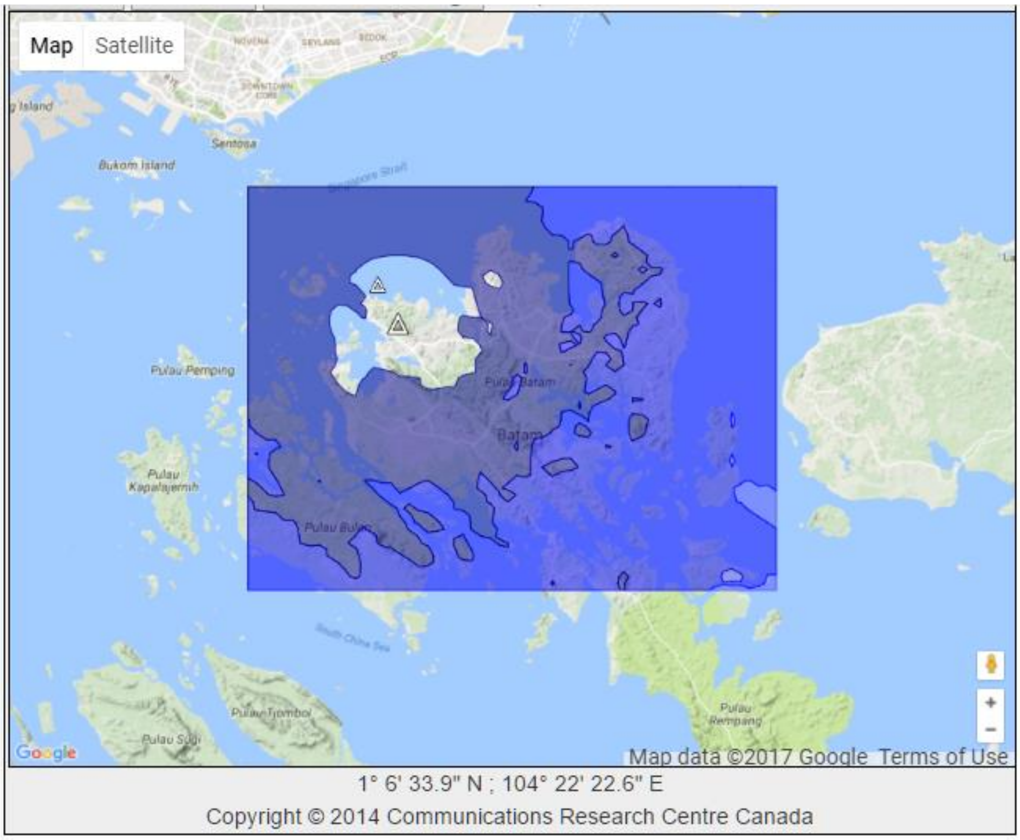
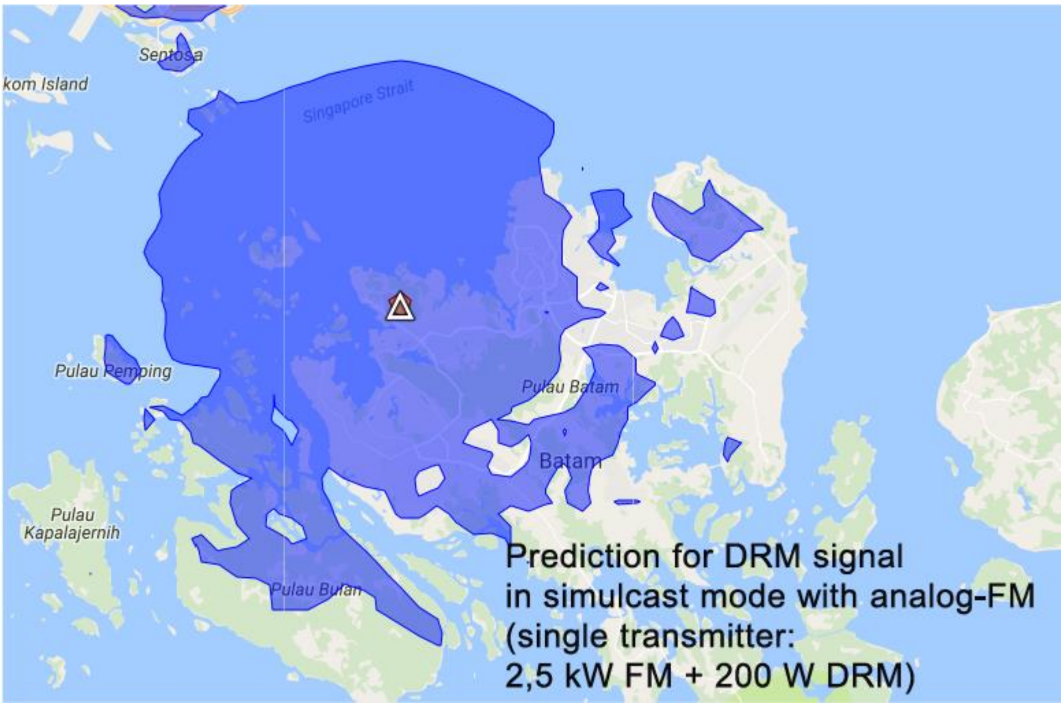



FIGURE 16

**Prediction Simulation Coverage by DRM Consortium**



# 5 Transmitter apparatus for testing

For DRM+ broadcasting, it is possible to use existing transmitters through the upgrades / modifications of available transmitters. Various FM transmitter models that have been produced in the last 5 years have been designed to have compatibility to be used as FM transmitters or DRM + digital transmitters

The RADIO REPUBLIK INDONESIA Batam transmitter used for the simulcast FM and DRM + transmission trials was the Programa 1 unit on 105.1 MHz operating with 5 000 watt power with the addition of a DRM + module / card in modulator / exciter FM transmitter, as shown below in Figures 17 and 18:

FIGURE 17

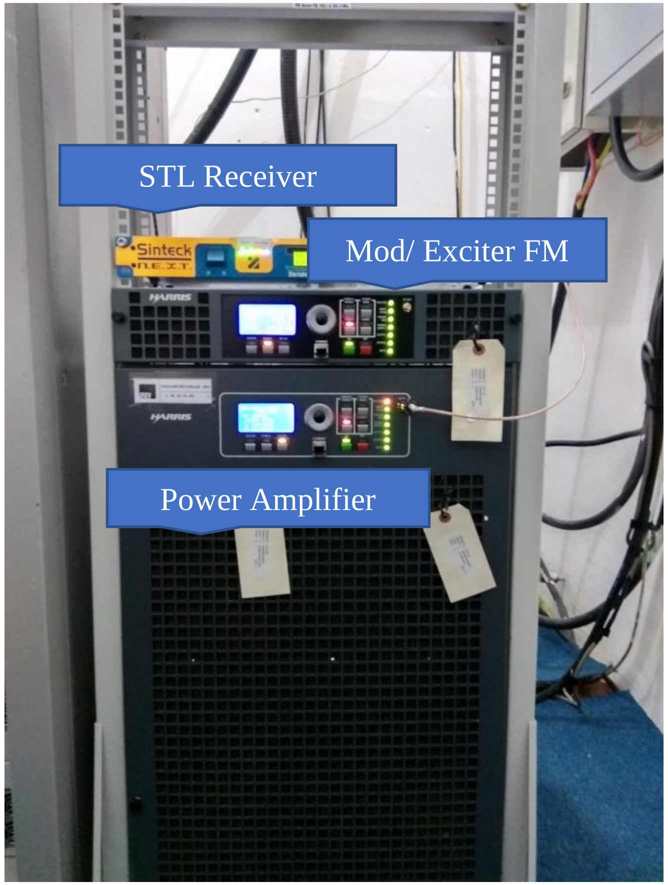
| | |
|---|---|
|   |  |
| Pemancar 5 000 watt | Modulator/ Exciter TX FM |

FIGURE 18

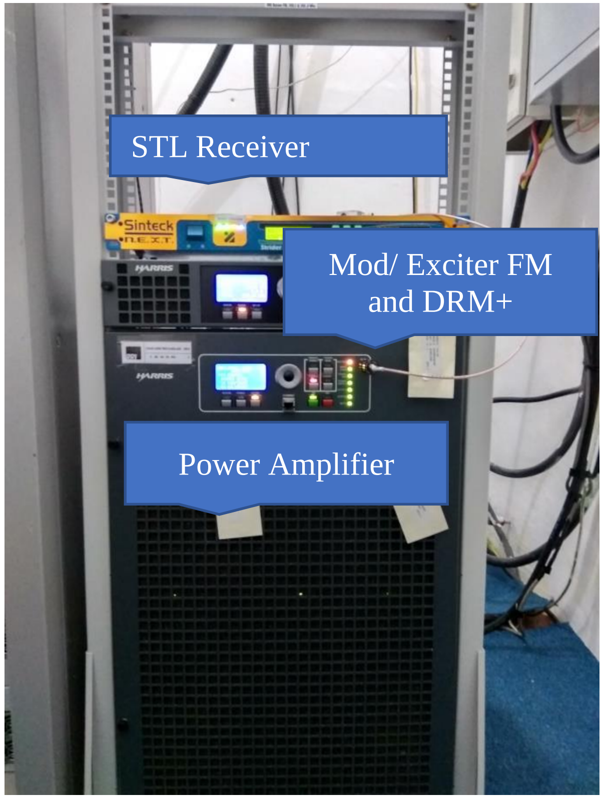
<table>
<tr>
<td></td>
<td></td>
<td>
</td>
</tr>
<tr>
<td>Module/ Card</td>
<td>Module/ Card DRM inserted</td>
<td>Pemancar 5 000 watt</td>
</tr>
</table>

FIGURE 20

**The DRM module / card is added to the analogue FM transmitter / exciter modulator**

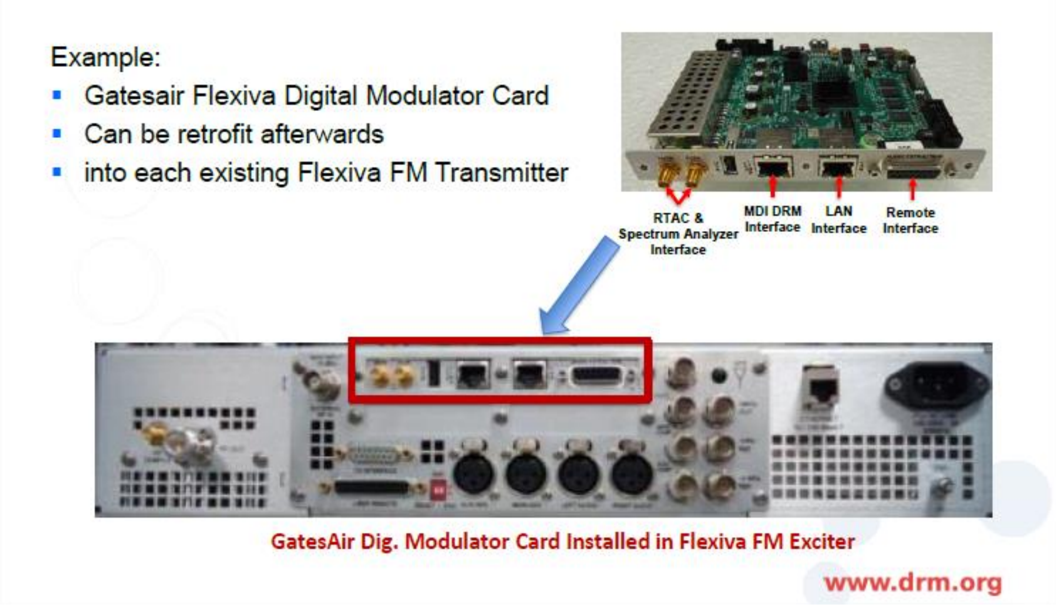
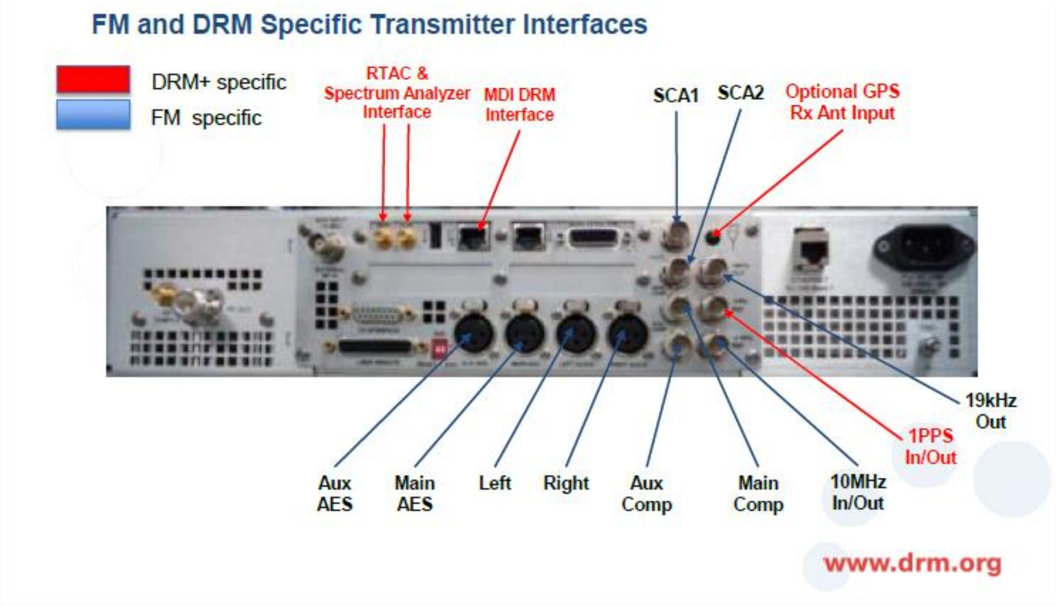



FIGURE 21

**Rear View Modulator / Exciter FM transmitter after added module for DRM**



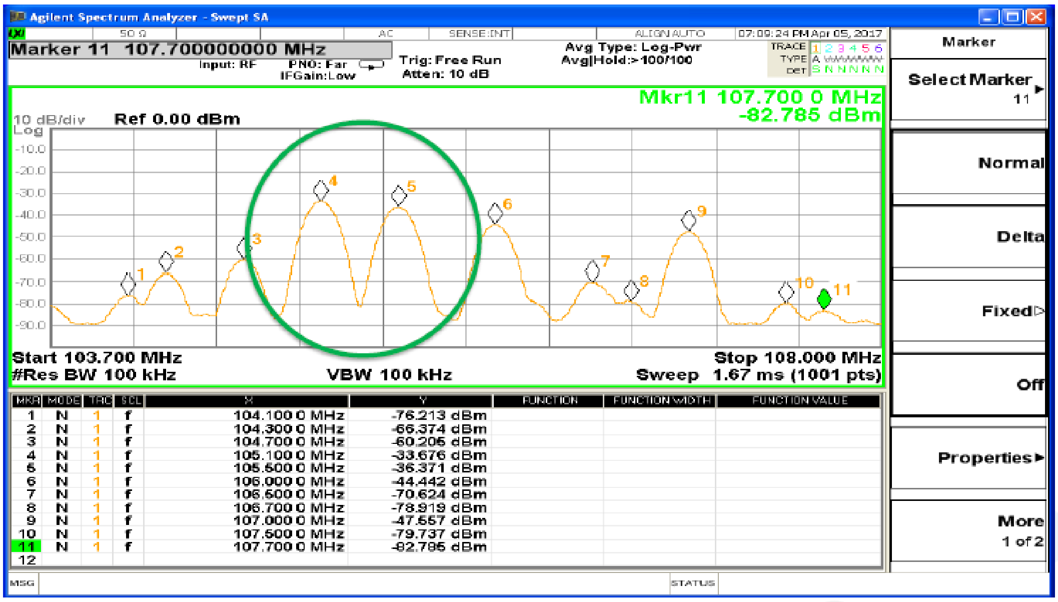

## 5.1 The simulcast and DRM + simulcast broadcasting results

Figure 22 below shows the frequency spectrum of FM transmitters in Batam operating between 103.7 and 107 MHz before the simulcast trials had begun.

The green circle shows the dominant feature of the Programa 1 and Programa 2 FM transmissions of Radio Republik Indonesia. Progama 1 transmits on 105.1 MHz and Programa on 105.5 MHz, i.e., with a carrier separation of 400 kHz.

FIGURE 22

**FM broadcasting transmissions in Batam**




*(Source: DRM Consortium)*

For the execution of the DRM + trial in Batam, modifications were made to the transmitter used in order to generate a DRM + signal, as described above. The program content for the DRM + trial was created from a 30 minute stream of both audio / sound services and the Journaline services recorded into the content server and then run by Multiplex Distribution Interface player ( MDI Player) as a continuous loop.

The analogue FM simulcast and DRM + transmitter output power settings used were:

– FM = 2.5 kW,

– DRM + = 200 watt.

The set-up parameters used for the trial are shown in Table 2.

TABLE 2

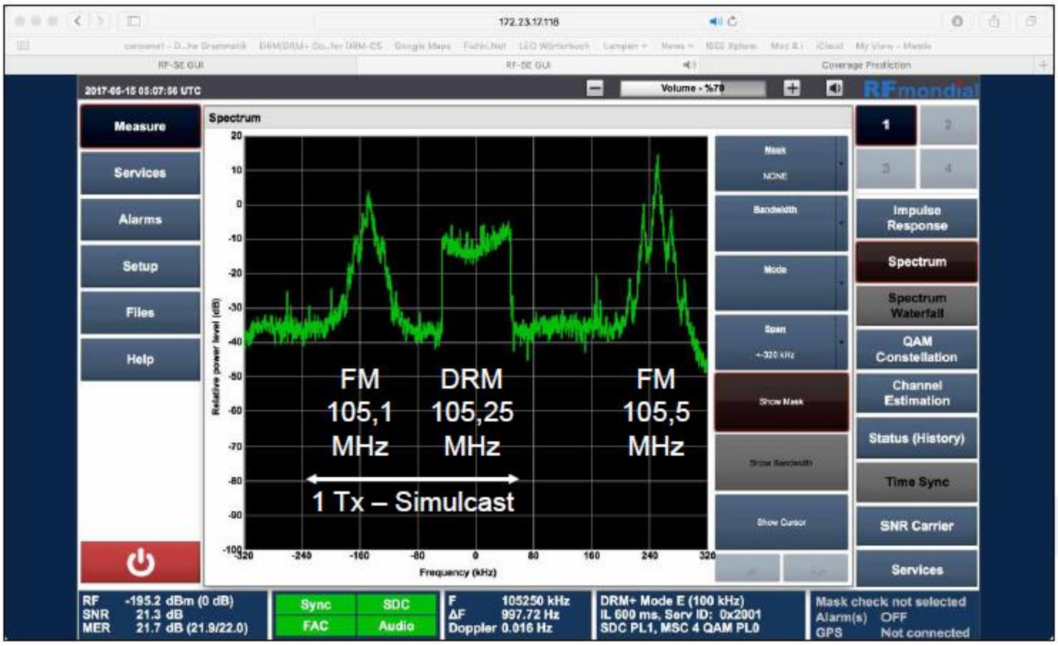
**Transmission parameters**

| DRM Parameters | Simulcast Mode FM+DRM |
|---|---|
| Transmitter Power | 2.5 KW |
| The DRM signal | 10 dB – 12 dB lower |
| DRM Mode | Mode E (DRM+) |
| Modulation | 4QAM |
| Protection Level | PL0 |
| Content (The 30 minute content was pre-recorded and plays in the Loop | 2 Audio Services (16kbit and 17.7 kb/s ) and Journaline Service |
| Minimum field strength | Mobile reception 40dBuV/m |

Figure 23 shows the frequency spectrum after the analogue FM and DRM + simulcast broadcasts commenced.

FIGURE 23

**Spectrum analyser display**




This display of the receiver demodulator output shows:

– the centre frequency of the FM transmitter Programa 1 at 105.10 MHz (no change);

– the combined / incremental DRM + signal centred on 105.25 MHz with 100 kHz bandwidth;

– the centre frequency of the FM transmitter Programa 2 at 105.50 MHz (no change);

## 5.2 Drive test measurement of field strength to determine the quality and extent of the transmitter coverage

The set-up of the measuring and monitor equipment is shown in Figure 24:

FIGURE 24


The predicted coverage of the DRM + transmission is shown in Figure 25 and the results obtained from the measurements of the field strength and assessment signal quality during the drive test are shown in Figure 26.

FIGURE 25

**Predicted coverage of Expert Team simulation results from DRM Consortium**

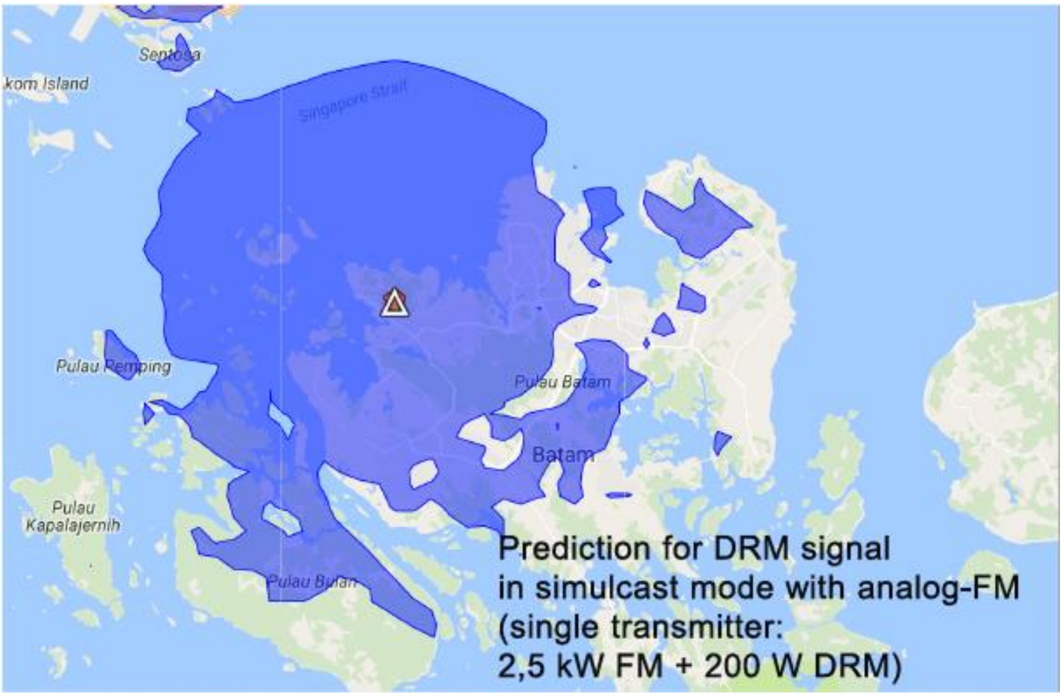
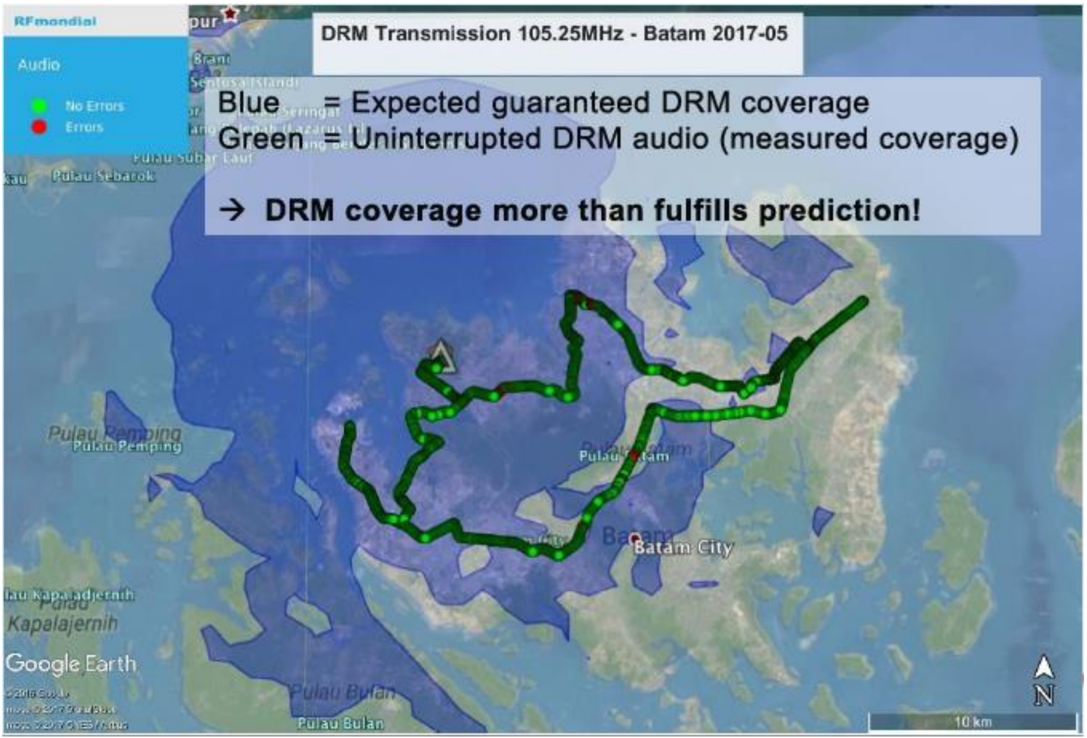


FIGURE 26

**Result of the coverage measurements, showing that the DRM + coverage exceeds the coverage prediction (Green dots are an uninterrupted audio reception)**




Figures 27 to 30 show the DRM + receiver visual status display.

FIGURE 27

**RRI On-Air Content display on DRM + trial**

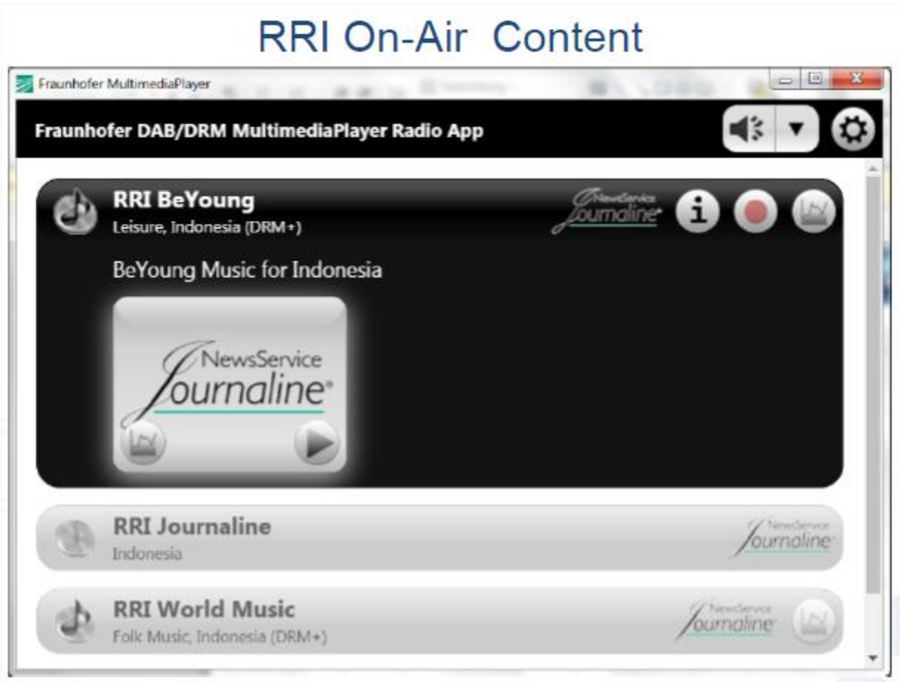


FIGURE 28

**RRI On-Air Content display on DRM + trial**


FIGURE 29

**RRI On-Air Content display on DRM + trial**

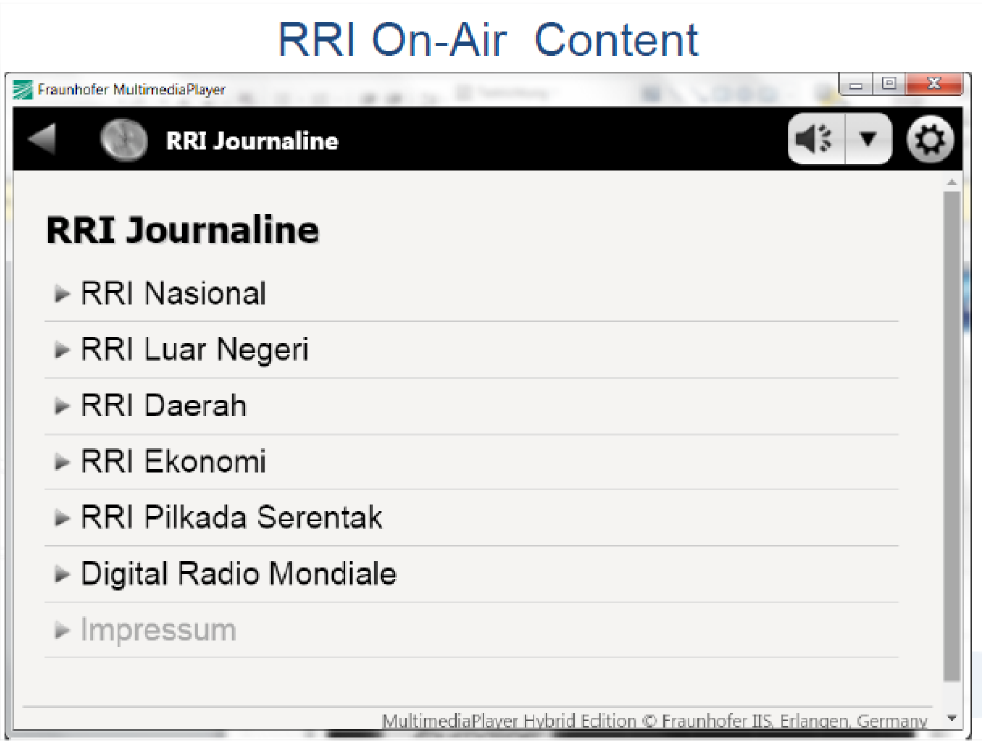


FIGURE 30

**RRI On-Air Content display on DRM + trial**


The overall field strength and signal quality measurement results are shown in Figures 31 to 33:

FIGURE 31

**Signal Quality Modulation Error Ratio**

FIGURE 32

**Strong field quality / monitored strength**


FIGURE 33

**DRM + audio quality – NB: error / disturbance detected at red dots, caused by man-made noise (motor vehicle)**


## 6 Conclusions

1) In transmitting experiments using 1 (one) transmitter simulcast FM and DRM + has been proven that the transmitter can function simultaneously emit FM signal at frequency 105.10 MHz and DRM signal at frequency 105.25 MHz,

2) FM 2.5 kW transmitter and transmitter DRM + 0.2 kW,

3) The DRM + signal is inserted on the existing VHF band II frequency spectrum,

4) Predicted DRM coverage areas that have been calculated are 40 dBμV / m,

5) Indoor reception (indoor) and mobile (mobile) quality is good,

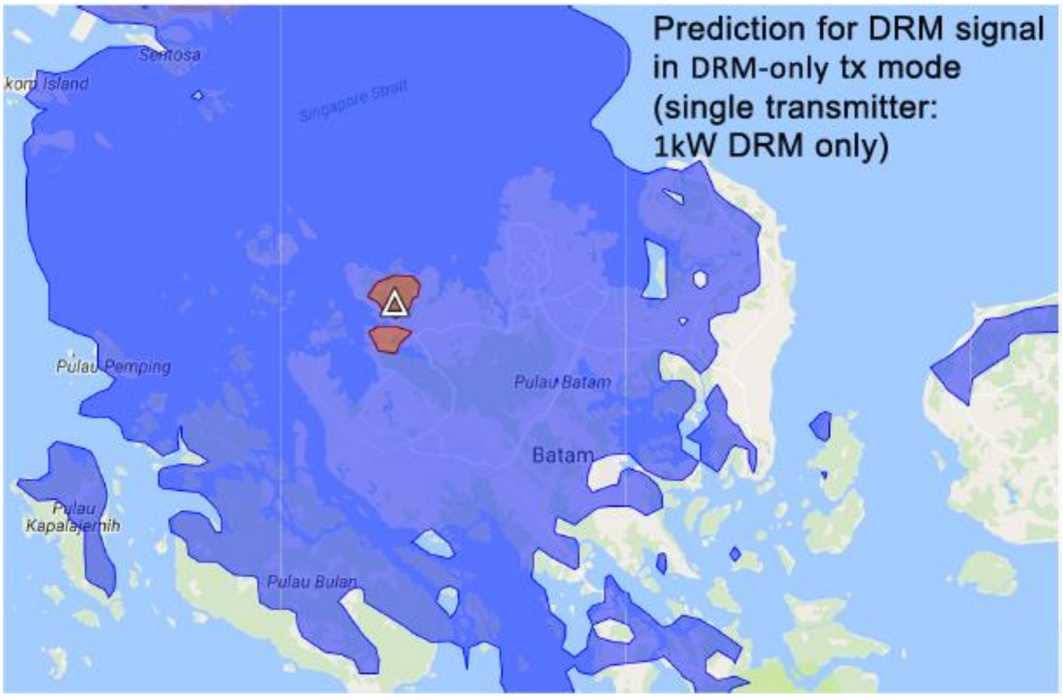
6) Wider DRM coverage area although with DRM transmitter only about 10% FM transmitter power,

7) No disturbance to the adjacent FM broadcasts (frequency 105.10 MHz and frequency 105.50).

8) Prediction for full digital DRM broadcasting is required with only 1 (one) DRM transmitter with 1 kW power (see Figure 34).

FIGURE 34

**Coverage over Batam City required only one DRM + transmitter with power 1 kW (full digital)**




## 7 Recommendations

1) Develop roadmap for implementation of digital radio broadcasting DRM +;

2) Conduct socialization and roadshow for Radio Republik Indonesia work units and stakeholders throughout Indonesia on digital radio broadcasting via DRM +;

3) Conducting education and training related to digitalization by means of DRM + digital radio broadcasting system for all Radio Republik Indonesia human resources throughout Indonesia;